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MR. JOHN BIRKINBINE in the chair.

THE UNDEVELOPED MINERAL WEALTH OF NEWFOUNDLAND.

BY A. E. OUTERBRIDGE, JR.

The island of Newfoundland, situated at the main entrance to the great Gulf of St. Lawrence, enjoys the distinction of being the oldest land, in a geological sense, in the new world, and the first land upon which was established an English-speaking colony in America.

Mr. James P. Howley, F.G.S., Director of the Governmental Geological Survey of Newfoundland, says:

"The appellation of *Terra-Nova,* or New Land, given to

this island by the early navigators, is one of the most ridiculous misnomers conceivable—at least in a geological sense.

"It is, in reality, a very old land, and had an existence, in large part as dry land, when but one small rock in the northeast corner of Great Britain represented that island. The 42,000 square miles, comprising the total area of Newfoundland, are made up of the oldest known geological formations, beginning with the Laurentian and ending with the Carboniferous. Not one of the higher or more recent Mesozoic systems, known to geologists, have any existence here, always excepting the superficial drift, chiefly made up of glacial *débris*, river silt and ordinary clays, derived from disintegration of the surface rocks."

With respect to the date of discovery of Newfoundland, there has been, and still is, some dispute, but the preponderance of evidence is, I think, clearly in favor of the contention that on June 24, 1497, John Cabot landed upon the island and took possession in the name of King Henry VII of England, by whom he was commissioned to explore new lands.

This was only five years after Columbus "sailed the ocean blue," and was more than a century before the landing of the Pilgrim fathers on the shores of New England.

Much interesting and valuable evidence in favor of this claim is presented by Judge D. W. Prowse, Q.C. (Judge of the Central District Court of Newfoundland), in his admirable history of that island, published in 1895 by Macmillan & Co.

Judge Prowse had access, through the favor of Lord Salisbury, to rare unpublished papers and historical records of the Elizabethan era, and Mr. Edmond Gosse, in a prefatory note, states that the work is an original and valuable contribution to early American history, and that the new material was "obtained from records which are, many of them, entirely unpublished."

Judge Prowse gives copies of entries found in the expense accounts of Henry VII, showing gratuities paid to Cabot and his men immediately after their return to England, as rewards for their discovery of the new-found-land.

It is not within the province of this paper to review the his-

tory of the expedition of John Cabot, although it is full of interest. A brief reference must suffice to indicate the scope of these investigations to those who may desire to explore the subject more fully.* Through the kindness of a friend, who has been a resident of Newfoundland for many years, I am able to present, in an appendix, an extract from a letter recently received, giving an interesting general description of some of the characteristic features of the island.

In 1881, the late Alexander Murray, F.R.S., then Director of the Geological Survey, published an official geological chart and survey of Newfoundland, made by Mr. Jas. P. Howley, then assistant geologist, who states that as long ago as 1778 a copper mine was opened at Shoal Bay, near Petty Harbor, on the eastern coast. This was probably the first attempt at mining, and copper mining is the most important mineral industry to-day, or rather it is the most fully developed. The official year-book of Newfoundland for 1897 gives tabular statements of imports and exports for the fiscal year ended June 30, 1896, and it therein appears that copper, in the form of ingots, regulus and green ore, was exported during the year to the amount of 64,672 tons.

The principal forms in which copper ores occur are copper-pyrites, glance, tetrahedrite (or gray copper ore), and specimens have been brought in, from outports around Conception Bay, of a very beautiful blue ore of copper, which is probably chrysocolla, or silicate of copper (Cu, 45 per cent.; Si, 34 per cent.).

Lumps of native copper are quite common in a matrix of calc-spar from Blue Mountain Tolt, near Salmon Cove.

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*The charter granted by Henry VII to Giovanni Cabotta (John Cabot) and his three sons—Sebastian, Sancti and Lewes—is dated March 5, 1496, and authorizes Cabot "to sail to all parts, countries and seas of the East, of the West and of the North, under our banner and ensigns, with five ships, and to set up our banner on any new-found-land as our vassals and lieutenants."

Cape Bona Vista, on the southern coast of Newfoundland, is now generally believed to be the point where Cabot landed and established the first English Colony five years after the discovery of the new world by Christopher Columbus.

The copper glance, or vitreous copper, will readily melt in a candle flame, and yields 80 per cent. of copper and 20 per cent. of sulphur.

Tetrahedrite, or "gray copper," as the miners call it, has (approximately) the following composition:

	Per Cent.
Cu	35
S	30
Sb	20
Zn	3
As	7
Fe	5

These are important commercial ores, which have been brought into St. John's from many localities; especially valuable are the copper glance, yellow pyrites and erubescite, from the neighborhood of Placentia Bay and elsewhere. Galena and zinc-blende, or "black jack," and calamine (silicate of zinc) are found in calcareous veins in the lower Huronian formation.

Galena (87 per cent. lead, 13 per cent. sulphur) is found in quartz veins at Tickle Harbor, Trinity Bay and in many other localities; the gangue being calc-spar, brown-spar and occasionally barytes. The best known vein, the "La Manche," is a good example of this form. At Little Placentia small fissures occur, in which a rich argentiferous galena is found associated with zinc-blende and specular iron ore.

Mr. Alexander Murray stated in his report (1881) that specimens from these veins yielded as high as 159 ounces of silver per ton.

"On a few blasts being inserted near the outcrop, one of these veins was found to increase rapidly in thickness and some rich-looking specimens were shown me as the produce. Three such veins were seen to contain ore, and were traced over the surface across a projecting point of the shore about 100 yards. There is great probability, that, owing to the disturbed state of the strata here, generally, these are droppers to a stronger and better defined lode which might reasonably be expected to occur somewhere in the neighborhood."

So far as I am informed, silver mining has never been successfully prosecuted to any extent, although the earliest his-

torical records show that silver was known to exist and this aroused great expectations of future wealth.

About a year ago, two samples of quartz were sent to me from the island for assay for gold and silver. Both specimens closely resembled gold-bearing quartz rock, but analyses gave only microscopic beads or traces of gold and silver, after cupellation with lead.

Iron ores are very plentiful, and a Nova Scotia company has operated for several years quite extensively at Bell-Isle, Conception Bay. The export of iron ore is rapidly growing; the ore is found near the surface, is very economically mined and is loaded on board steamers which run close under the high bluffs and take the ore directly into their holds through chutes. It has been found that the cinder refuse, commonly called "blue billy," from the Newfoundland pyrites, after extracting the sulphur in the manufacture of sulphuric acid, is almost entirely free from sulphur and is a valuable by-product, used in the manufacture of steel. It commands a higher price than similar cinder from any other source.

The Newfoundland year-book for 1897 shows that the export of iron pyrites has increased from 410 tons in 1887 to 36,496 tons in 1896.

Nickel is found in the serpentines, and was worked in a primitive fashion at the Union Mine, Tilt Cove, until the fall in price of nickel rendered the operations unprofitable.

Coal has been found in workable seams at St. George's Bay and on the line of the new governmental railway, which is now almost finished and will be opened during the coming autumn. This railway is a belt line, 564 miles in length, starting from the capital, St. John's, running northward near the coast for more than 100 miles, then veering inland, crossing the island from east to west and running down the coast to the southwestern extremity. This point is only about 80 miles distant from Cape Breton Island across the mouth of the Gulf. A fine fast steamer will convey passengers in a few hours from the railway terminus at Cape Breton to the Newfoundland railway terminus. Prospectors, tourists and others will thus be able to reach all parts of the island within three days' jour-

ney from New York, and will avoid the tedious and sometimes dangerous sea voyage from Halifax.

Returning, after this brief digression, to the subject of my address, I am able, through the kindness of Mr. Howley, to give some further statistics from a paper published by him in 1892. Mr. Howley states that a copper mine, known as the "Bett's Cove Mine," was opened in 1875, and actively worked for ten years, during which time 130,682 tons of ore and regulus were exported therefrom, besides 2,450 tons of iron pyrites. The ore occurs in a mass of mixed chloritic slate and diorite. In the course of the excavating some enormous pockets of ore were uncovered.

In 1885, the bluff caved in, owing to having been honeycombed by the excavations, and, although it is thought that the ore was far from being exhausted, operations were discontinued. "The Little Bay Mine was opened in 1878, and before the end of the first season 10,000 tons of ore were raised and shipped to Swansea. Between 1880 and 1885, 61,776 tons were shipped from this mine, and since that date to the end of last year (1891) over 40,000 tons of ore, regulus and ingots of copper are given in the customs returns. Between 1880 and 1882 the Southwest Arm Mines yielded 490 tons; Hall's Bay, 240 tons; Rabbitt's Arm Mine (worked only one year), 1,260 tons, averaging 28 per cent. copper."

The variety of iron ores is very large, and there is little doubt that in future years an extensive export of hematite will be developed, which is found of the richest variety, containing 70 per cent. iron; besides chrome and other ores.

The sample of chrome ore on the table before you, recently received from Newfoundland, was analyzed by the well-known firm of Booth, Garrett & Blair, with the following results:

	Per Cent.
Chromic sesqui-oxide	50
Prot-oxide of iron	40
Silica, etc.	10

This ore is the valuable source of bichromate of potash used so largely in dyeing and paint-making. Chromate of potash or soda is first produced from the ore, and from this base the

bichromates, and all of the other pigments, greens, yellows, blues, browns and reds, are obtained.

A remarkable circumstance connected with this industry, which is not generally known, is, that the entire business is in the hands of two families, one in Europe and one in this country. It is said that time and again expensive works have been erected and new chrome products put upon the market, but the old manufacturers have invariably succeeded in killing all opposition by the simple method of reducing prices until the new makers were driven to the wall. As these two firms create the only market for chrome ore, the mine owners are at their mercy. According to Mr. Frederick H. Smith, a well-known geologist of Baltimore, chrome ore containing 60 per cent. of chromium sesquioxide has been sold in that city at $42 a ton.

Two years ago several samples of crude petroleum were sent to me from the west coast of Newfoundland. This was a heavy mineral oil, resembling the Lima fuel oil, and was pronounced by experts an admirable lubricant. I was informed that the samples were obtained by spreading blankets upon the surface of a stream on which the oil floated. The oil was absorbed by the blankets and then squeezed into buckets.

Since that time a well has been bored and the letter, appended hereto, states that a considerable flow has been secured.

There are quite a number of other economic minerals, such as plumbago, manganese, asbestos, rutile, steatite, mica, mineral pigments, etc., of which I cannot now speak in detail.

I can only pause a moment in concluding this address to allude to the great variety of fine building stones found all over the island.

"Granites, syenites, porphyries of every shade of color and consistency, and immense deposits of pure white statuary and mottled marbles range from the mouth of the Humber River northward, towards White Bay, and are again met with in Canada Bay.

"Amongst these are beautifully veined, pale pinkish, bluish, drab, yellowish and some black varieties, all of which take a high polish."*

*Report of Jas. P. Howley, F.G.S., 1892.

A granite quarry was opened several years ago, which is, I believe, unique in the fact that, owing probably to some great convulsion of nature in past times, the granite has been split into rectangular blocks of various sizes, and of such regular form that schooner loads of selected stones have been procured, ready for the builder's use. In fact, there are buildings in St. John's constructed of these cubical blocks which have been dressed by nature's hand only. If any similar instance is on record, I have failed to find it.

While I have only been able to touch lightly upon the subject of the undeveloped mineral wealth of Newfoundland, I think you will all agree with me that this island may be truly called a natural cabinet of minerals, which will, perhaps, at no very distant day, be opened up for the benefit of mankind.

It is certainly remarkable that this oldest colony of Great Britain in the new world should have remained to this day in so primitive a condition. Until the pathway for the iron rails was blazed across the island the interior was almost a *terra-incognita,* and even now many parts of the interior have never been visited by white men.

History relates that a tribe of aborigines, called "Bethuks," existed on the island when John Cabot landed there in 1497, and two of the savages were taken to England by Sebastian Cabot, where they created much interest. But this tribe has long since disappeared, and there are no native Indians or Esquimaux inhabiting the island.

The coast of the island is exceedingly rugged, and its outline is extraordinarily irregular, being indented with innumerable bays, some of great size. Vast herds of caribou range through the interior, the rivers are alive with salmon, which may frequently be seen leaping rapids, and the smaller streams are filled with speckled trout.

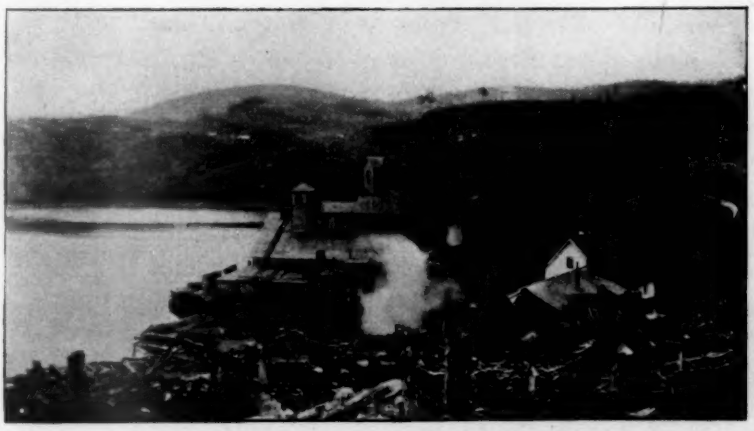
It is said that the simple fishermen dread to venture inland beyond the sound of the ocean, but the opening of the railway will undoubtedly change all of these primitive conditions and lead to an influx of sportsmen, tourists and prospectors.

The Government of Newfoundland realizes that the time has come when the mineral wealth of the country should be

Iron mine at Bell Isle, Conception Bay, showing surface workings.

Iron mine at Bell Isle, Conception Bay, showing ore chutes and loading pier; 1,800 tons of ore were loaded in steamer *Regulus* in 4¾ hours.

Copper mine at Little Bay. Total output about 200,000 tons.



Pyrites mine at Pilley's Isle. Employs a fleet of ships.

	$3,000,000	30,412	1,750,000	55.73	48,732,840	21,605	1,949,313	90.22
	1,553	1,578	16,295	10.64	509	513	2,625	

developed, and is therefore offering every facility to explorers. License fees to secure a large mining area are fixed at the nominal sum of $20. There is a museum in St. John's, where specimens of all of the minerals which have been discovered are preserved, labeled and catalogued, this is under the charge of the Director of Surveys. Geological reports are furnished from which valuable information regarding the economic minerals may be obtained.

The summer season, though short, is delightful; and an erroneous impression prevails regarding the rigors of winter. Very low temperature is almost unknown, and deep snows are rare. The capital, St. John's, is further south than London, being in the same latitude as Paris. The occasional grounding of large icebergs a short distance from the shore produces astonishing local climatic changes, delaying the ripening of crops and garden fruits, but presenting at sunset magnificent prismatic or iridescent effects.

The coastal steamers, which carry the mails to the outlying ports, as far up as the coast of Labrador, afford an easy means of viewing the bold bluffs and of visiting the mines, all of which are located close to the seaports.

The island is 360 miles in length, and at its broadest part is somewhat wider than its greatest length, but in some places narrow strips of land only separate the great bays indenting the coast on all sides. There are no mountains; but the precipitous bluffs and high hills rising abruptly from the water's edge convey the impression of a mountainous country.

APPENDIX.

[FROM A PRIVATE LETTER.]

The island of Newfoundland has always been so associated with the suggestions of "fog and cod" that probably many people may have imagined its mineral resources to be connected with its general trade and covered by the metal-producing stamp called "C. O. D.," but such is not the case.

The rock-bound shores have scarcely yet been scratched, though thousands of tons of copper, iron pyrites and lead have been shipped, and there is little doubt that a brilliant field is there open to the prospector who will turn his steps a short distance inland, where heretofore, owing to the absence of communication with the coast, scarcely any one has thought it worth while to seek.

Many years ago, a gentleman stood upon the shores of Placentia Bay and observed some fishing smacks approaching the land. Suddenly a squall heeled over one of the boats and revealed a brilliant carmine below the water-line.

On arrival, the skipper was interrogated as to whence the color was obtained. "Over yonder, under the cliff, is a great block of it," he replied, "which, when ground with oil, produces the paint."

Mr. Charles Fox Bennett, the pioneer of mining in Newfoundland—for this was the gentleman—went to the spot indicated, and there found an enormous block of silver ore which had fallen from the cliff. It was too late in the year to prosecute the search further, but the following spring Mr. Bennett arrived with miners, equipped to commence work; but alas! a great landslide had effaced his landmarks, and from that day to this, although many efforts have been made, the supposed rich vein has not been discovered, although indications of its existence have been not infrequent.

Mr. Bennett subsequently opened and worked the Tilt Cove Copper Mine, which has produced abundant supplies of copper and nickel and a small percentage of gold. This mine is still worked by the Cape Copper Company.

Practically no prospecting has been attempted, except on the immediate coast line, but that little has given indications of valuable deposits of many minerals, some of which are about to be vigorously worked by the railway contractor, Mr. Reid, and others. A large surface deposit of iron ore on Bell-Isle was worked last summer by the New Glasgow Steel Company, and other deposits are to be worked during the approaching season, both on the east and west coast.

Until very recently the whole west coast was a forbidden land, owing to the disputed claims of the French; but those difficulties have been partially removed, and enormous known deposits of chrome and other iron ores are likely to be worked in the near future. Workable seams of coal have been discovered, and the new railway will probably be run with native coal during the present year.

Petroleum has also been found on the west coast, and one boring is already yielding a considerable flow.

Asbestos is frequently found on the line of the railroad, but this has not been developed.

The Pilley Island Pyrites Mine employs a fleet of steamers to transport the mineral to the United States. Numerous other deposits are known to exist, but heretofore, the paucity of local capital has prevented their commercial development.

THE UTILIZATION OF ALUMINUM IN THE ARTS.*

BY ALFRED E. HUNT.
President of the Pittsburgh Reduction Company.

[*Concluded from vol. cxliv, p. 113.*]

Aluminum has been used *in the construction of yachts,* in the sheathing, decks and other construction above the water line, for the purpose of allowing a greater sail area to be carried without danger of the vessel becoming "cranky" or top-heavy. The victorious yacht *Defender* exhibits a total saving made by the use of aluminum of over 7 tons, the hollow steel boom and gaff of tubular construction also saving another ton of weight.

The tensile strength of the nickel-aluminum plates of *Defender,* which were ¼ inch, 5-16 inch and ⅜ inch thick, 6 inches to 28½ inches wide, and 9 feet to 18 feet 8 inches long, was 40,000 pounds per square inch, with an elastic limit of 30,000 pounds per square inch, and an elongation of 8 to 10 per cent. in 2 inches, the reduction of area at point of fracture being 11 to 15 per cent. The modulus of elasticity was 11,500,000 pounds.

Aluminum is being used in our navy *for lavatory slabs,* airport shutters and many special castings for various purposes. Aluminum is used in bulkheads particularly for the purpose of preventing danger from shattered pieces of flying wood, due to the action of shells which may pierce the outside plating of a ship in action.

There is a constant and growing demand for nickel-aluminum plates, rivets, bulb-beams, angles and other sections for yachts and steamers of light construction.

Where aluminum is to be alternately exposed to moisture and dryness, corrosion is likely to occur, and this is especially liable to be serious in salt water. In order to protect the metal, it is necessary that it should be coated with an impervious varnish.

*A lecture delivered before the Franklin Institute, March 26, 1897.

Mr. A. H. Sabin has described in the December (1896) number of the *Transactions* of the American Society of Civil Engineers, an interesting set of experiments on "The Protection of Aluminum Exposed to Sea-Water," by the aid of certain special varnishes.*

An important use for *aluminum* which has just been started is *for parts of furniture.* Book-cases, rat- and vermin-proof, have been neatly made, and are receiving favorable attention from various public libraries.

A serious difficulty is being encountered in the furniture trade because of the difficulty of brazing aluminum sheet into tubing in the way that brazed brass tubing is made. This trouble, however, has already been partially met, and bids fair to be entirely overcome in the near future.

As a conductor of electricity, aluminum has received considerable use in the arts, and is destined to have much larger future applications. Pure aluminum has a conductivity of 63 to 64 per cent. It is practically non-magnetic, and may, therefore, be used for many purposes in electrical work where a magnetic metal would be useless; at the same time, its electrical conductivity is excellent, as the table printed below, giving relative electrical conductivities of various metals, will show.

Aluminum may, therefore, in the future be largely used *in*

*The aluminum sheets were exposed in sea-water in the Brooklyn Navy Yard for six months' time. Those of the first series, coated with a black enamel, showed absolutely no corrosion when taken out.

Those with a second preparation, called "Durable Metal Coating," made by the Edw. Smith Varnish Company, showed a slight corrosion on the unbaked sides of the sheets. The baked varnish on the sheets showed perfect results.

Another form of their varnish, called "Spar Varnish," with no pigment, one side of the sheets baked, showed on both sides perfect protection of the aluminum.

These plates were suspended in an open oak case or rack, in a horizontal position, about 2 inches apart; the plates being fitted loosely in the rack and suspended at the four corners. The rack was suspended from a float, 6 inches or so below the surface of the water.

The water of the Brooklyn Navy Yard carries considerable sewage and sulphides, occasioning very considerable corrosion with steel or copper plates.

the windings of field-magnets on dynamos where saving of weight is an object, and in general for switches, brushes, brush-holders and apparatus, where its non-tarnishing and non-corrosive qualities should render it specially valuable.

As is the case with other metals of good electrical conductivity, the conducting power of aluminum is greatly decreased as the result of the presence of alloying metals. Pure aluminum has a much higher conductivity relatively to pure copper than is ordinarily given in the books. The lower figures of the earlier determinations were occasioned by the considerable impurities that were present in the aluminum then employed for testing its relative electrical conductivity.

In the early part of the year 1896, tests made of aluminum wire manufactured by the Pittsburgh Reduction Company, by Mr. Charles F. Scott, at the electrical testing laboratory of the Westinghouse Electric Company, and also by Prof. Jos. W. Richards,* at Lehigh University, gave the following results in electrical conductivity.

These samples of aluminum were ·0282 of an inch in diameter, and of the following composition:

	Per Cent. Pure Aluminum.
Sample No. 1	99·50
Sample No. 2	99·00
Sample No. 3	98·00
Sample No. 4 (about)	97·00
Sample No. 5 "	96·00

The impurities in each case were chiefly silicon and some iron.

Sample No. 4, XB, was nickel-aluminum alloy, used in rolling into stiff sections. This alloy contained about 97 per cent. pure aluminum.

Sample No. 5, XCWC, was a stiff alloy, containing copper and zinc, and about 96 per cent. pure aluminum.

Fifty feet of each sample of wire were tested, the wire being wound on wooden spools and immersed in oil. The temperature was varied by placing the spools so immersed into a steam heater, the oil being kept thoroughly stirred. Resistance

* *Jour. Frank. Inst.* **143**, 195.

measurements were made by means of "Wheatstone's bridge."

The resistance of soft, pure copper wire, 1 foot long and 1-1000th of an inch in diameter (unit foot), was taken as 9·720 B. A. units at 0° C.; corresponding to 9·612 legal ohms at 0° C., or 10·20 legal ohms at 15·5° C.

The results of the tests made by Mr. Chas. F. Scott were as follows:

Sample.	Ohms per 1,000 feet 'or inch diameter at 15° C.	Per cent. Conductivity at 15° C.	Per cent. Variation per deg. between 15° C. and 80° C.
Pure copper wire	101·83	100·00 per cent.	·388
No. 1, 99½ per cent. pure aluminum	161·40	63·09 "	·385
No. 2, 99 " " "	163·80	62·17 "	·385
No. 3, 98 " " "	181·30	56·17 "	·360
No. 4, XB, nickel aluminum alloy	174·10	58·48 "	·361
No. 5, XCWC, copper-zinc aluminum alloy	185·10	55·01 "	·359
Result of Prof. J. W. Richards on the 99½ pure aluminum	—	64·50 "	·300

Relative Electrical Conductivity.

AUTHORITY, ROBERTS-AUSTEN.

Silver (pure)	100·00
Copper "	97·61
* " (refined)	97·50
Gold (pure)	76·61
†Aluminum (pure)	63·00
Magnesium "	39·44
Sodium "	31·98
Zinc "	29·57
Cadmium "	24·38
Calcium "	21·77
*Brass (35 per cent. zinc)	21·50
Potassium (pure)	19·62
Lithium "	18·68
Cobalt "	16·93
*Iron (Swedish)	16·00
Iron (pure)	14·57
Platinum (pure)	14·43
Tin "	14·39
Nickel "	12·89
Bronze (10 per cent. aluminum)	12·60
Palladium aluminum	12·08
*Steel (Siemen's)	12·00

Thallium	(pure)	9·13
Lead	"	8·42
Strontium	"	6·60
Arsenic	"	4·68
Antimony	"	3·59
Mercury	"	1·75
Bismuth	"	1·40
Tellurium	"	·0007

*Authority, Lazare Weller. †Authority, Scott & Richards.

M. Charpentier-Page, in the impression of *L'Electrochimie* for April, 1896, publishes electrical conductivity results obtained under his direction, as follows:

ELECTRICAL CONDUCTIVITY.

Pure copper	100
Commercially pure aluminum	62
Aluminum, 97 per cent.; copper, 3 per cent.	49
" 94 " " " 6 " "	44
" 10 " " " 90 " "	13

The wire tested having a diameter of 2 millimeters.

Already the Pittsburgh Reduction Company has furnished several hundred miles of *aluminum wire for movable telephone and telegraphic work.* The facts that the weight of copper wire is 3·3 times greater, and that the tensile strength of the two materials is not very different, have made the use of aluminum wire for field military telephones and telegraph lines especially advantageous.

In castings, *aluminum* alloyed with about 5 per cent. of copper to harden it is just beginning to be used to replace brass castings *in electrical apparatus.* The aluminum alloys used are as easily tooled and take as good threads as brass castings, and the electrical conductivity of the alloys used has been fully up to that of ordinary brass, and better even than that of ordinary copper castings, for the reason that copper, as it is ordinarily treated in making castings, absorbs a great deal of oxygen, which causes it to have markedly lower electrical conductivity than rolled copper, which, although reckoned at 100 per cent., is often lowered to 30 per cent. in copper castings. Nickel-aluminum castings have been made with a conductivity of 50 per cent. in the same scale.

The tensile strength of ordinary copper castings is about 19,000 pounds per square inch, and, in the best results with specially prepared copper castings, has never exceeded 30,000 pounds per square inch, while the nickel-aluminum casting alloys can readily be supplied of a tensile strength per square inch of 25,000 pounds.

The high degree of purity which it is possible to reach in manufacturing aluminum, as well as the purity of the commercial article, compares favorably with that of copper or any of the common metals, as the following table will show:

TABLE SHOWING PURITY OF ALUMINUM COMPARED WITH OTHER METALS.

	Purest Commercial Product. Per Cent.	Purity of Commercial Metal. Per Cent.
Aluminum	99·90	99·30
Copper	99·95	99·50
Zinc	99·70	99·30
Tin	99·10	98·50
Nickel	99·50	99·00
Lead	99·60	99·00
Iron (in softest steel)	99·85	99·80

Stiff *aluminum sheet* has had quite an extensive use *for card- and book-cases.* The covers of many important record books are now made of aluminum sheet, well rounded at all edges to prevent the subsequent wear of the leather used in connection with the metal sheet upon the books. Several firms are making convenient little pocket tablets to be held in aluminum sheet metal cases, a sample of which is shown. These pocket tablets are especially popular with physicians for their pocket prescription tablets.

The finish of these aluminum sheets has been varied by different methods of working. In scratch-brushing, a brass scratch-brush is run at a high rate of speed. This work can be modified by first taking a leather wheel and very fine Connecticut sand, revolving at a very high rate of speed on a polishing lathe, feeding the sand at the same time between the wheel and the aluminum metal so that the skin and irregular surfaces are removed, then putting the metal on a buffing wheel for scratch-brushing. In this way, a variety of different effects can be produced. A fine brass scratch-brush gives a most

beautiful finish to sheet metal or to articles manufactured from the sheet. By this means, a frosted appearance is given to the metal, an effect which in many cases is equal to that given by a high polish.

An appearance similar to the scratch-brush finish can be given by sand-blasting. The effect of first sand-blasting and then scratch-brushing sheets gives a finish with very much less labor than with the scratch-brush alone. Another very pretty frosted effect is secured by first sand-blasting, and then treating as hereinafter described under the head of "Dipping and Frosting."

A very pretty mottled effect is secured on aluminum goods by first polishing them and then holding them against a soft pine wheel run at a high rate of speed on a lathe. By careful manipulation quite regular forms can thus be obtained. This can be varied by first scratch-brushing or sand-blasting, and then holding the articles against a wheel as previously described. Aluminum which has been sand-blasted receives a grain which will allow of printing on the surface of the sheet with the best results, and aluminum sheets thus prepared are coming very largely into use for photo-lithographic purposes. The surface in such cases is first sand-blasted in order that it will take and retain the ink, and produce very clear and sharp outlines when printed from. The faces for cyclometer dials, watch dials and similar articles are generally sand-blasted before they are printed upon, which gives a very fine white background.

Directions for Dipping and Frosting.—Remove the grease and dirt from the plates by dipping in benzine. To whiten the metal and produce a handsome frosted surface, the sheet should be first dipped in a strong solution of caustic soda or potash; then in a solution of undiluted nitric acid; then washed thoroughly in water, and dried in hot sawdust. The sawdust must be of a fine, dry grade, with no resin or pitch that will streak the surface.

For Burnishing.—Use a bloodstone or steel burnisher. For hand-burnishing, use either a mixture of melted vaseline and kerosene oil, or a solution composed of two tablespoonfuls of

ground borax dissolved in about a quart of hot water, with the addition of a few drops of ammonia.

Lubricant.—The best lubricant to use on aluminum when being turned in the lathe is either kerosene or water; and in the press, when the metal is being drawn or stamped, vaseline.

Tooling.—The best results in working aluminum can be derived by using a "shearing tool," or, in other words, a tool which is shaped more resembling one used in working wood than for working iron or brass, thus securing a tool with a sharp point, which gives the metal an opportunity to free itself, rather than clog the cutting edge. Tools of all descriptions can be made on this principle, regardless of the purpose for which they are intended, whether to cut a thread or turn to a surface.

Benzine is considered the best lubricant on engravers' tools to obtain a bright cut on aluminum, although naphtha, kerosene, or a mixture of coal oil and vaseline is sometimes used. The benzine is preferred, owing to the fact that it does not destroy the satin finish in the neighborhood of the cut, as the other mixtures will sometimes do, if they are not carefully handled. There is, however, as much skill required in using and making a tool for a bright cut, as in the choice of the lubricant that is used.

Speed Used for Spinning or Buffing.—The best work in spinning aluminum on chucks from 5 to 8 inches in diameter can be performed by running the lathe at 2,600 revolutions per minute. Of course, as the diameter decreases for small articles, this speed can be increased up to 3,200 revolutions per minute, and on chucks larger than 5 or 8 inches in diameter the speed would be decreased somewhat below that given.

In buffing aluminum, the best work is produced by using a buffer from 8 to 10 inches in diameter, at speed of about 3,800 revolutions per minute.

Very fine effects can be produced by first burnishing or polishing the metal and then stamping it in polished dies, showing unpolished figures in relief.

Polishing.—An erroneous idea has become prevalent that aluminum does not require cleaning or polishing. All metals

exposed to the influence of the atmosphere and moisture become tarnished and soiled to a greater or less extent, even though, as is the case with aluminum, the actual oxidation of the surface is almost *nil.* A thin film of "matter out of place," called by the housewives by the general name of "dirt," will form upon aluminum as it does upon gold.

Almost any good metal polish will cleanse aluminum. It is necessary, however, that the polish should contain no coarse grit. The ordinary metal polishes used for nickel, silver, etc., usually contain too much coarse material and scratch the surface of aluminum.

It will be found that if aluminum receives one-half the attention that is given to brass, copper, silver or nickel, it will retain its polish with much less labor and remain in a brighter condition than any of these metals.

Aluminum will take and retain a very high polish*—fully equal to that of silver. The truly distinctive and beautiful color of aluminum is brought out in a highly polished plate. Aluminum can be polished on buffing wheels with rouge, the same as brass, and for polishing any considerable quantity of sheet, this method is the most economical.

In the great continental scourges that have played such havoc in far-away parts of the world during the past year—the rinderpest in Africa, the famine and plague in India, as well as in the war between China and Japan—*aluminum* has played an important alleviating part in the form of metallic *covers or cases for compressed foods* hermetically sealed in oil-paper packages. These cases not only form serviceable light covers to protect the food and allow of its rapid distribution in the afflicted districts, but also serve as convenient dishes in which to heat and cook the food at the time of its consumption.

A novel use for *aluminum,* which is likely to become quite a large one, is in *tea-caddies or boxes for the shipment of tea* from the far-away countries of China, India, Japan and Ceylon, where the tea is grown.

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*There are many aluminum polishes on the market. Among those to be recommended are: Acme aluminum polish, "Bon Ami" and ordinary rouge polish.

The common practice now is to ship tea in wooden boxes, lead-lined and sealed in specially prepared paper. Tea-boxes are now being made of thin aluminum sheets about 5-100ths of an inch in thickness, weighing about 7-10ths of a pound to the square foot, the sheets being riveted together in water-tight boxes of the metal, with angles at the inside corners for holding the riveted joints together. The aluminum sheets are given a satin finish on the outside to allow the special printing and marking of the boxes as desired by the tea merchants. These aluminum tea-boxes are lighter and cost but little more than lead-lined wooden boxes that have heretofore been used.

In the use of *aluminum for structural purposes*, the selection of the proper grade that should be used will depend largely upon the specific purpose to which it is desired to apply the metal; but generally speaking, for purposes where aluminum is brought into tension, such as in sheets, or in rolled shapes (as angles, beams, etc.), an ultimate tensile strength of from 32,000 to 40,000 pounds per square inch may be reckoned upon; and a safety factor of 4, gives an allowable working strain of from 8,000 to 10,000 pounds. This, of course, is not for pure metal, but for the stronger alloys.

The ultimate tensile strength of pure metal in plates and shapes may be taken at from 24,000 to 28,000 pounds, and with the same safety factor of 4, it gives an allowable working strain of from 6,000 to 7,000 pounds.

For the alloys of cast aluminum in tension, the ultimate strength may be taken at from 18,000 to 28,000 pounds per square inch; using a safety factor here of 5, as aluminum castings are quite uniform and solid, a working strain is obtained of from 3,600 to 5,600 pounds per square inch.

It is difficult to give a value for the ultimate strength of pure cast aluminum in tension, for the reason that while the ordinary pure aluminum will average about 16,000 pounds per square inch, this can be increased very considerably by cold working, and in some cases to as much as 24,000 pounds per square inch. Assuming the average strength and using a safety factor of 4, gives an allowable working strain of from 3,200 to 4,800 pounds.

In comparison, the alloys of aluminum in rolled plates and structural shapes, such as struts, columns, etc., have an ultimate tensile strength of from 26,000 to 34,000 pounds per square inch, which, using a safety factor of 4, gives an allowable working strain of from 6,500 to 8,500 pounds per square inch.

Pure aluminum sheets and structural shapes in compression have an ultimate tensile strength of from 20,000 to 24,000 pounds per square inch, which, with a safety factor of 4, gives an allowable working strain of from 5,000 to 6,000 pounds per square inch.

Castings of aluminum, in comparison, can be taken at 16,000 pounds per square inch for pure aluminum, and from this to 24,000 pounds per square inch for the alloys. Using again a safety factor of 5, an allowable working strain is given of from 3,200 to 4,600 pounds per square inch. But the pure metal should not be used in castings, except for electrical purposes, as it resembles pure copper in being difficult to cast, and is soft, comparatively weak, and has a large shrinkage. In its stead for most casting purposes, alloys with from 5 to 20 per cent. of copper, nickel or other hardeners should be used.

The alloys of aluminum in rivets and similar shapes in shear have an ultimate shearing strength of from 24,000 to 27,000 pounds; which, using here a safety factor of 6, gives an allowable working strain of from 4,000 to 4,500 pounds per square inch.

The ratios of the ultimate shearing strength to the ultimate tensile strength for double-riveted joints is about 60 per cent.; and for single-riveted joints the ratio is about 70 per cent. The ratio for steel is about 75 per cent.

In bearing, the ultimate value of the alloys of aluminum is from 32,000 to 40,000 pounds per square inch; which, using a safety factor of 4, gives an allowable working strain of from 8,000 to 10,000 pounds.

The attention of those contemplating the use of aluminum for structural purposes is called to the fact that the elastic limit is closer to the ultimate tensile strength than in any other of the commercial metals, and for this reason the safety factor of

4 or 5 means a great deal more than it does in steel or iron, where the same safety factor is used.

Where any great strength in aluminum is desired, the metal should be protected in such a way that its temperature will not be raised very much beyond that of the ordinary atmospheric temperature, for the reason that aluminum melts at a little less than 1,200° F.

The values given above are for temperatures of less than 100° C. (212° F.); for temperatures between 100° and 200° C., the unit strain should be decreased by 50 per cent., and above 200° aluminum should not be designed to be used in strain.

For the *purifying of drinking water,* aluminum is destined to take an important part. Our civilization is just being wakened up, by an increased knowledge of bacteriology, to the necessity of purifying the water supplies of large cities.

For this purpose alum and sulphate of alumina have been used for a considerable time. The active principle of the alum in doing this work has long been known to be the hydrated oxide of aluminum; and it has of late been demonstrated that this freshly precipitated hydrated oxide of aluminum can be prepared from metallic aluminum better than by adding the considerable proportion of sulphate of alumina that has heretofore been used.

Dr. Lugo has suggested the placing of aluminum plates as electrodes in the water to be purified, passing an electric current therethrough, the decomposition of the aluminum largely depending on the amount of impurities in the water. It has been shown that by this process the impurities in the water are coagulated with the hydrated oxide of aluminum around the anodes, and the water thus materially purified.

A process of purifying water has been patented, which consists in subjecting it to the action of a coagulant composed of a comminuted alloy of aluminum and then separating the coagulum from the water through a sand or other suitable filter. The inventor prefers an alloy of aluminum with tin, or some other metal electro-negative to aluminum, with the idea that the aluminum will be decomposed and the water purified

more readily than by the use of the pure aluminum for the purpose.

Dr. Lugo, with his plant using the electric current, proposes to force the current (of about 4 volts) through the liquid from anode to cathode, and estimates that with the plant which he had in hand he will decompose about 3 pounds of aluminum per day with 1 horse-power, or 100 pounds of aluminum with about 30 horse-power.

So far, no very large business has been developed with the use of aluminum for the purification of water; but the process is now being actively exploited, and the prospects are that in a little time it will be largely developed.

The rationale is that the gelatinous hydrate of alumina is one of the best purifying agents for water, and that this can be produced in more effective form from aluminum plates immersed in the water than by the addition of a salt to produce the alumina, which, in the case of sulphate of alumina, would leave considerable sulphuric acid in the water.

Aluminum hydroxide, freshly precipitated, has the property of coagulating animal or vegetable matter held in solution or suspension in the water, and of entangling a considerable portion of the minerals held in suspension, and these impurities are carried down with the precipitated hydrate. The addition of chemically prepared hydrate of alumina to the water does not seem to give the same desirable result, the action of the nascent hydrate, when this is generated in the water, seeming to be much more effective than when the already-formed hydrate is added to the water.

Should this process develop as it bids fair to, it would mean a very largely increased demand for aluminum.

For the *minor coinage,* aluminum seems, in some of its hardened alloys, to be peculiarly well adapted. Prof. Jos. W. Richards has preceded me in the Institute* with a very interesting paper, the statements of which, as to the advantages of aluminum for coinage, from my own experience, I can heartily endorse. Already, several countries, including the United

*See *Jour. Frank. Inst.*

States, India and several South American States, have started to investigate the relative merits of aluminum alloys for the minor coinage. The present 1-cent pieces of the United States (1896) weigh 48 grains troy, and the specific gravity is ·8782. There are 146 of them to the pound.

Their chemical composition is:

	Per Cent.
Copper	95
Tin	3
Zinc	2

The blanks for the 1-cent pieces are 15-20 inch diameter and ·043 inch thick.

The standard 5-cent pieces of the issue of 1896 weigh 77·16 grains troy, and there are 93 of them to the pound.

The chemical composition of same is:

	Per Cent.
Copper	75
Nickel	25

The blanks are 16-20 inch diameter, the thickness being ·062 inch.

The Government has of late been paying for the 1-cent pieces 16½ cents per pound, and for the 5-cent pieces 31·94 cents per pound.

Pure aluminum blanks submitted to the mint for trial have been criticised as too soft, producing a burred edge before the design is brought out upon the dies, with indications of the dies becoming clogged in the working of the aluminum.

This has been occasioned largely by the fact that the same pressure and conditions were used in striking up aluminum coins as in striking the harder metals at present in use for the 1-cent and 5-cent pieces. With the coining presses adjusted for the working of softer metal, in pressure and clearance of dies, etc., it will be quite practicable to stamp up satisfactorily a coin from pure aluminum sheet; but it will undoubtedly be better to use for the purpose a metal which is harder than pure aluminum. Alloys of aluminum with about 10 per cent. of hardening ingredients are now being experimented with, and will, I am confident, be found in the future to be satisfactory

for our minor coinage; the alloy being a cheaper material in the cost per hundred blanks for the fabrication than is at present charged for the 1-cent and 5-cent pieces.

Aluminum can readily be alloyed in the manufacture with a small but identifying amount of such metals as titanium, molybdenum, vanadium or similar metals, which would readily distinguish counterfeits by the analysis of the composition, as arrangements could be made with the Government that this particular alloy would not be made up by the aluminum manufacturers except for the purpose of coinage, and it will be found difficult to make these alloys with aluminum in a commercial and economical way, except as they would be made in the reducing pot in the first manufacture of the aluminum.

Rich alloys of these ingredients could be made with from 5 to 10 per cent. of alloying ingredients, the analysis of the alloy made and the material diluted with pure aluminum until it had one-tenth of 1 per cent., or whatever other proportion was decided upon as the distinguishing amount of the ingredients of titanium, molybdenum or the like for the purpose.

A committee of the 54th Congress has been appointed to investigate the relative merits of nickel and aluminum alloys for the minor coinage, and this committee's work will undoubtedly be continued during the session of the 55th Congress.

Aluminum has been extensively used *in brushes and combs.**

Aluminum combs sawed out of hard nickel-aluminum sheet are also convenient and cleanly, and are now becoming quite popular. [Samples of an aluminum brush and comb were shown to illustrate the facts stated.]

Aluminum has been used largely *for military equipments*, especially in European armies, where they are closely watching to cut down from the, at best, heavy weight to be carried by

*The Florence Manufacturing Company, of Florence, Mass., have been not only pioneers in the use of aluminum for hair brushes, but have also brought out the most satisfactory hair brush yet put upon the American market. They have a novel process by which the bristles of the brush are held in place and made to protrude through the aluminum cases on the front side of the brush. Also, the aluminum back made by them is certainly a very durable, useful, practical and satisfactory innovation in the manufacture of hair brushes.

the soldier in heavy marching order equipped for field service.

In canteens, buttons, belt-plates, rings for shelter tents, shoe-pegs and metal parts of the scabbard and sword-handle, aluminum is being largely used. It is probable that it will only be a short time before a much larger use of aluminum for these purposes will be found in this country.

Aluminum has been used *for burial cases or caskets* of various kinds. So far the metal has been only used in the most expensive kinds of caskets, which have sold at retail at not less than $500 each, and this, of course, has made the sale of aluminum caskets a limited one. But when it is taken into consideration that at most there is only $50 to $60 worth of aluminum, at present prices, in the most elaborate aluminum caskets, and that it will be quite possible to make either cast or built-up caskets from plates riveted together, at a cost not to exceed (including the cost of the aluminum) from $75 to $90, it would appear to be only a question of time when aluminum will be very largely used for this service. The metal can be made up into very ornamental shapes for caskets, and its durability will be very considerable. From hygienic considerations, these caskets will surely receive favor among undertakers in the future. It is true that many of the forms of embalming fluids used in preserving bodies contain chloride of zinc, chloride of arsenic, and often some free chlorhydric acid, which will act upon and corrode aluminum. Still it will be practicable to avoid such corroding action by putting lime or similar salts into the caskets, underneath the casket linings, to entirely absorb and neutralize the corroding liquids referred to, and prevent their action upon the aluminum.

The *soldering of aluminum* has so far proved a difficult task. Most solders, such as ordinary hard solder, composed of silver and tin, or ordinary soft solder, composed of lead and tin, will not stick, owing to the high heat conductivity of aluminum. The heat is very rapidly drawn away from any of the molten solders, causing them to "freeze" before flowing sufficiently. Good joints, however, can be made by carefully cleaning the surfaces to be joined, and with very hot soldering bits, or careful work with the blow-pipe, "tinning" the surfaces

with some of the special solder used before attempting to join the metals. Several such solders are successfully used, pure tin, with a little phosphor-tin, being the basis of the majority of such solders.

One of the earliest solders proposed for aluminum was that proposed by your fellow-member, Mr. Joseph Richards, who I understand was awarded a medal by the Franklin Institute for his solder, in which phosphor-tin plays an important part.

Another solder for aluminum, made by Edw. N. Cook, 144 Pine Street, Providence, R. I., is called "Green's Aluminum Solder." It is not used with any flux, simply requiring the aluminum faces to be cleaned and first coated with the solder; then with a clean, hot soldering bit, to "wipe" the solder joint to be made.

Green's solder is composed of:

	Per Cent.
Zinc	50·03
Tin	47·99
Aluminum	1·76
Phosphorus	·22

Many fluxes have been proposed in soldering aluminum. Common stearine, as used in wax candles, has been found as efficient as any. Soldering bits of nickel are best to be used, and specially good work has been done with those kept hot by a gasoline torch or electric appliance. Special care should be taken to clean the surfaces to be soldered, which can be successfully accomplished by the mechanical means of scratch-brushing, scraping or filing the surfaces, thus exposing fresh metal free from the thin film of oxide of aluminum and the oxide of silicon (silica), which forms a resistant and protecting coating over the surface of the metal, preventing either the soldering or plating of aluminum.

Another way to clean the surface of aluminum either for soldering or plating is to dip the sheets into nitric acid diluted with three times its bulk of hot water, and which has had added to it just enough hydrofluoric acid to make the solution act on the surface of the metal, this action being denoted by the evolution of gas bubbles. The solution can be kept in either a wooden or lead-lined tank, and the amount of hydrofluoric acid added

need be only small, say, less than 5, or at most, 10 per cent. of the volume of the solution. The hydrofluoric acid required is the cheap fluid of commerce sold in lead jugs and costing about 5 cents per pound. The aluminum, after being cleaned in this dilute nitric acid and hydrofluoric acid solution, is again dipped into hot water for rinsing and dried in hot sawdust; it is then cleaned so that either solder or plating solutions can readily be applied.

The difficulty of making durable soldered joints of aluminum lies in the galvanic action which takes place between the aluminum and the metals composing the solder. The common metals are decidedly electro-negative to aluminum in a voltaic couple, and as the electro-positive element is the one attacked first and most severely and the electromotive force (or force produced by the difference in chemical action between aluminum and any of the common metals with which it comes in contact in a voltaic element) is equal to the sum of the electromotive forces between all the intervening metals, it follows that care should be taken that aluminum exposed to water or other solutions should not come in contact with any other metal which will cause a voltaic couple to be formed.

Aluminum can be protected in places where it is exposed to galvanic action by insulating with rubber or canton flannel soaked in a mixture of white lead and oil, or some other non-conducting substance. It can also be protected by placing between the aluminum and the metal with which it is in contact a more electro-positive metal, such as magnesium, where the metal from which the aluminum is insulated is electro-negative to it, as is the case with most metals.

The following table shows what metals are electro-positive or electro-negative to one another:

POSITION IN ELECTRO-CHEMICAL SERIES.

(IN THE ORDER OF THE MOST POSITIVE FIRST.)

1 Caesium,	6 Barium,	11 Chromium,
2 Rubidium,	7 Strontium,	12 Manganese,
3 Potassium,	8 Calcium,	13 Zinc,
4 Sodium,	9 Magnesium,	14 Gallium,
5 Lithium,	10 Aluminum,	15 Iron,

16 Cobalt,	27 Silver,	38 Boron,
17 Nickel,	28 Antimony,	39 Nitrogen,
18 Thallium,	29 Tellurium,	40 Arsenic,
19 Indium,	30 Palladium,	41 Selenium,
20 Lead,	31 Gold,	42 Phosphorus,
21 Cadmium,	32 Iridium,	43 Sulphur,
22 Tin,	33 Rhodium,	44 Iodine,
23 Bismuth,	34 Platinum,	45 Bromine,
24 Copper,	35 Osmium,	46 Chlorine,
25 Hydrogen,	36 Silicon,	47 Oxygen,
26 Mercury,	37 Carbon,	48 Fluorine.

In the *electro-plating of aluminum*, as in soldering, it is necessary that the surface film of oxide of aluminum and oxide of silicon, which is found to exist on any metal which has been exposed for any length of time to influence of the atmosphere, should first be completely removed. This cleansing operation can be accomplished either by immersing in caustic alkali or alkaline carbonate, or immersing in a dilute solution of nitric acid with enough added hydrofluoric acid to cause evolution of gas on the surface of the aluminum. After the surface has been slightly acted upon, it should be rinsed in running water and dried in hot sawdust, if the metal is to be soldered. The surface of aluminum has also been cleaned for plating by boiling in a strong solution of washing soda, which gives a rough surface, with a good "bite" for the plating. The aluminum is then washed and dipped for a moment in a hot solution of hydrochloric acid, say, 50 per cent. It is then plunged for about one-half second into a vessel of clean water and instantly transferred to a three-tenths of 1 per cent. solution of copper sulphate with a trace of acid. The solution will deposit copper on the aluminum in an adherent layer. Also, some gas is evolved during the process. As soon as a uniform deposit of copper is obtained, which takes place in three or four minutes, the aluminum is washed with water and the plating continued in the usual way with copper, brass, silver, gold or other metal.

Several companies, in the past, have been selling sheet iron purporting to be plated or "galvanized," as they call it, with aluminum or with alloys of aluminum and tin. It is a fact that alloys of aluminum and tin can be coated on sheet iron according to the process outlined as having been carried on by the

Tacony Iron and Metal Company, of this city, for plating the iron columns on your Public Buildings; but in most cases the iron sheets purporting to be plated by aluminum have been found on analyses to contain no aluminum at all.

In the plating of the columns of the Philadelphia Public Buildings by the Tacony Iron and Metal Company, the process consisted of plating the metal with an alloy of 75 per cent. aluminum and 25 per cent. tin. The iron columns were first cleaned and then electro-plated with copper in an alkaline bath, a thickness of something like 1-16th inch of copper being obtained in an acid sulphate bath. The aluminum-tin alloy was deposited at a temperature of 130° F., at a current density of 8 ampères per square foot, from pure aluminum anodes, in a bath having the following composition:

	Parts.
Saturated solution aluminate of soda	75
Stannate of soda	25

The bath also contained some potassium cyanide.

The following is a method for plating on aluminum:

The aluminum is immersed first in a bath of acetate of copper dissolved in vinegar, to which oxide of iron, some sulphur and aluminum chloride have been added (*sic*). This gives a deposit of copper over the surface. After this, the article is brushed with a soft brass wire brush and well rinsed in clear water, and is then placed in the electrolytic bath to be plated in the usual manner. If the work is well done, this plating is so strong that no amount of bending will cause it to chip off or crack.

After being plated with silver or copper, the article may be treated by the sulphide process for "oxidizing," giving the same effect as "oxidized silver."

Aluminum is now sold at a price per pound about equal to that of nickel, and not largely in excess of that of German-silver; volume for volume, it is much cheaper than German-silver; and for replacing German-silver or britannia metal *as a base in silver-plated vessels*, its power of retaining heat and its lightness, together with its much cheaper price, will certainly present such advantages as will cause its extensive use.

In the aluminum trade, the manufacturers have been confronted with the anomalous position that it is necessary for them to sell the metal at prices to compete with brass in sheet, wire, tubes, etc., as cheaply as similar articles are sold in brass. To do this, they have been obliged to put in the plant for the efficient and economical working of aluminum in sheets, bars, wire, tubes, etc., upon a scale sufficiently large to produce the best results, and that before the business was sufficiently developed to warrant the installing of the plant.

The brass manufacturers have the advantage of a large business already established, with many plants working under the most economical conditions as to their facilities for rolling, drawing, etc.

It has been the experience so far that the establishments having these facilities for working in brass are not willing to work aluminum at anything like the same relative prices, but have desired a profit of from 50 to 100 per cent. beyond that with which they were content in brass for similar work in aluminum, so that the manufacturers of aluminum have found themselves in the unsatisfactory position of having to put in their own rolling mills and drawing apparatus of the most approved pattern in order to compete in price for work in similar articles of brass. To be compelled to put in the considerable plants necessary for working aluminum at the same time they were developing the business for increasing the output of the ingot metal has proved considerable of a hardship to the manufacturers of aluminum.

So far as the experience of the Pittsburgh Reduction Company goes, it is about the same for an aluminum plant as for a steel plant—that it takes about one-fourth the area of the plant for the actual manufacture of aluminum ingots, and three-fourths of the occupied territory for plant in working up the metal in foundries, rolling mills and the like.

Aluminum has now reached a point in selling price where it is about equivalent to brass for many purposes. Brass averages from 3·15 to 3·20 times heavier than aluminum; and when the price of brass per pound is multiplied by this factor, it will be seen that aluminum to-day is really a cheaper metal than

brass, for many purposes, and that it will in the future be a question of the "survival of the fittest" between the two metals.

It will take years before workmen will gain the experience in handling aluminum as adeptly as brass, occasioned by life-long experience in working brass. It will take years before the stock of dies will have accumulated with the proper clearance for aluminum over that needed for brass; so that even with aluminum eventually coming out the superior metal, manufacturers must reckon upon only a gradual approach of tonnage of aluminum consumed to that of brass.

For many purposes brass is undoubtedly the superior metal. It is essentially a better bearing metal than aluminum. It can be brazed, as aluminum cannot be at the present time—a difficulty which handicaps aluminum from being used in place of brazed brass tubing, etc. Brass can be subjected to a higher temperature under working conditions than can aluminum with its lower melting point; and brass can be soldered more easily than aluminum, and the soldered joints made much more lasting.

Aluminum is a very sonorous metal, and it has been used quite extensively for gongs in the place of brass.

In metal sheets, whitened by scratch-brush or other form of satin finish, *aluminum has replaced brass for clock faces* to a considerable extent.

It is evident that for any use of aluminum in the form of sheets, bars, tubes, wire or castings, its light weight relatively to other metals should be taken into consideration in comparing the relative costs for any given purpose.

The common metals—wrought iron, cast iron, steel, copper, zinc, tin, lead, brass, bronze, German-silver, nickel, antimony and britannia metal are all much heavier; and the relative economy in using them in either the cast or worked shape can only be arrived at by multiplying the price of the heavier metal by the factor of its specific gravity relative to the specific gravity of aluminum.

For convenience in these calculations, the following table is given:

Metals.	Specific Gravity.	Factor of Specific Gravity relative to Aluminum.	Selling price per pound New York Market in May, 1896, in large lots.	Relative selling price per pound New York Market to Aluminum obtained by multiplying price per pound by factor given in column B.	Value per pound that Aluminum is thus relatively cheaper.	Value per pound that Aluminum is relatively dearer.
	A	B	C	D	E	F
No. 1 aluminum, cast	2·56	1·000	$0.35	$0.35	$ —	$ —
No. 1 aluminum, wrought	2·68	1·000	.45	.45	—	—
Commercial copper, cast	8·85	3·457	.1025	.354	.004	—
Commercial copper, wrought	8·93	3·332	.14	.466	.016	—
Tin, cast	7·29	2·848	.1345	.383	.033	—
Tin, wrought	7·36	2·746	.20	.549	.199	—
Bronze, 16 tin, 84 Cu, cast	8·832	3·451	.12	.414	.064	—
Bronze, 16 tin, 84 Cu, wrought	8·90	3·321	.18	.597	.147	—
Britannia metal, cast	7·261	2·836	.125	.354	.004	—
Britannia metal, wrought	7·301	2·724	.200	.545	.095	—
Twenty per cent. German-silver, cast	8·60	3·360	.16	.538	.188	—
Twenty per cent. German-silver, wrought	8·70	3·246	.2925	.949	.459	—
Nickel, cast	8·287	3·237	.35	1.133	.783	—
Nickel, wrought	8·67	3·235	.45	1.456	1.006	—
Brass, 33 Zn, 67 Cu, cast	8·32	3·250	.095	.309	—	.041
Brass, 33 Zn, 67 Cu, wrought	8·349	3·190	.12	.383	—	.067
Antimony, cast	6·71	2·621	.08	.210	—	.140
Lead, cast	11·36	4·438	.0308	.1367	—	.2133
Lead, wrought	11·38	4·247	.045	.1911	—	.2589
Zinc, cast	6·861	2·680	.0410	.1099	—	2401
Zinc, wrought	7·191	2·683	.06	.1620	—	2880
Steel, cast	7·82	3 055	.025	.0764	—	2736
Steel, wrought	7·858	2·932	.016	.0469	—	.4031
Iron, cast	7·218	2·820	.006	.0169	—	.3331
Iron, wrought	7·698	2·872	.015	.0421	—	.4079

The first uses to which aluminum was applied were naturally those which would stand the high cost of the metal at its selling rate of $10 to $15 per pound.

The first considerable use of the metal was for tubes of opera-glasses and other optical instruments. Then as the metal became lower in price, it was used in thin sheet and metallic foil in a similar way to gold and silver. It was also used in powder made from the foil. Thereafter came the use of the metal in the manufacture of a large line of fancy goods, where the cost of the metal used was a small proportion of the total cost, including the workmanship involved. These, for a considerable length of time, were the staple uses for aluminum; but the tonnage—or rather, to be more accurate, the "poundage"—of metal which could be used for these articles was of necessity very limited; and before the aluminum could be used like other metals, the price had to be materially reduced. This was done in the years 1891 and 1892—at first due to accidents of patent litigation, and before the companies then manufacturing aluminum by the present process had so far perfected the process and increased the capacity of their works really to warrant the decreased selling price by their cost of manufacture; but since the year 1892, with the greatly improved and extended facilities for production, introduced by the large manufacturers of aluminum, they have been enabled gradually to reduce the selling price, until to-day the rate is such that aluminum is a cheaper metal, section for section, than copper, and as cheap as brass.

One of the earliest banes of our commercial life in the *aluminum* business was communications, and in some cases interviews, with *flying-machine cranks*, who were very sure that with the aid of the new metal aluminum, which they maintained was three times as strong, as well as three times as light as steel, they should be able to accomplish that in which Darius Green had failed.

Impossible pieces of apparatus, in crude models, and often in sketches in which plan, elevation, section and projection were all sadly jumbled, were sent to the Pittsburgh Reduction Company, together with letters of interminable length, ordinarily in the poorest of penmanship and with words spelled askew. These people ordinarily imagined that because the Pittsburgh Reduction Company advertised to sell aluminum,

they should therefore manufacture any articles of the metal which might happen to be devised. Fortunately, the number of these inventors seems to be growing less; and it has been the good fortune of the Pittsburgh Reduction Company to have sold, to men of real scientific attainments, aluminum materials—mostly in the shape of hardened alloys—which have been successfully used in aëroplanes, balloons and other forms of flying-machines; and in whatever form the flying-machine of the future is to find its most successful developments, it is safe to predict that the use of aluminum as a structural material will have an important part.

Aluminum has been suggested for many purposes for which it is not adapted. Prominent among these may be mentioned cases where much soldering or brazing of the metal has to be done. Because of the difficulties I have already outlined, in soldering and brazing, the use of aluminum has, in most such cases, failed.

Another source of failure of the metal has been in attempts to apply it where gas or liquids are confined under heavy pressure in aluminum apparatus.

Aluminum has so far proved so open and porous in its texture as to be incapable of withstanding, in the form of castings, more than 100 pounds per square inch, without leaking. Undoubtedly, in the future, better work will be accomplished and aluminum castings will be made which will withstand higher pressures without suffering liquids or gases to percolate through the pores of the metal; but, so far as the writer is aware, this has not been found to be the case in commercial work of pure aluminum and alloy castings of the present day.

Another source of failure of aluminum in the arts has been the attempt to use it under high temperatures. The melting point of aluminum, according to the latest experiments, is 1,200° F. The "critical point," if I may be allowed to use this term in this connection, that is, the place where the metal begins markedly to lose tensile strength, is lower comparatively for aluminum than for metals of higher melting points. While it is true that copper, steel and similar metals all markedly lose in strength when heated to over 500° F., with

aluminum the temperature at which the metal begins to lose materially in tensile strength is between 300° and 400°; and the writer would not recommend the use of aluminum where the temperature is in excess of 300° F. This will preclude the attempts which have been made to use aluminum for steam boilers and steam apparatus of similar character where the pressure is high. It has been found that a small percentage of iron materially raises the melting point.

Aluminum does not volatilize at any temperature ordinarily produced by the combustion of carbon, even though the high temperature be kept up for a considerable number of hours. It, however, is not good practice in making castings of aluminum to heat it much above its melting point, or to allow it to remain melted for any great length of time, on account of its capacity for absorbing gases.

The latent heat of fusion of aluminum, according to Prof. Jos. W. Richards, is 29·50 calories (kilogrammes), or, expressed in heat units (pounds), 53·00.

The mean specific heat of aluminum from zero to the melting point is very high, being 0·2185, water being taken as 1. This means that the quantity of heat which would raise the temperature of any given quantity of aluminum through 1° would raise the temperature of the same quantity of water through ·2185 of 1° only. Aluminum follows the general law of specific heats, *i. e.*, that they are inversely as their atomic weights.

The linear expansion of aluminum is relatively very high, being exceeded only by zinc and lead of the common metals. The following table shows the expansion per degree per unit of length of the various metals in relative order:

COEFFICIENTS OF LINEAR EXPANSION.

AUTHORITY, ROBERTS-AUSTEN.

	Cent.	Fahr.
Potassium	·0000841	·0000476
Sodium	·0000710	·0000395
Indium	·0000417	·0000231
Cadmium	·0000306	·0000170
Thallium	·0000302	·0000168
Lead	·0000292	·0000162
Zinc	·0000291	·0000161

Magnesium	·0000269	·0000150
Aluminum	·0000231	·0000130
Tin	·0000223	·0000124
Silver	·0000192	·0000107
Tellurium	·0000167	·0000093
Copper	·0000167	·0000093
Bismuth	·0000162	·0000090
Gold	·0000144	·0000080
Nickel	·0000127	·0000071
Cobalt	·0000123	·0000070
Iron	·0000121	·0000069
Palladium	·0000117	·0000065
Antimony	·0000105	·0000058
Ruthenium	·0000096	·0000053
Platinum	·0000089	·0000050
Rhodium	·0000085	·0000046
Iridium	·0000070	·0000039
Osmium	·0000065	·0000036
Arsenic	·0000055	·0000031

The thermal conductivity of aluminum is very high, and is exceeded only by one of the baser common metals, *i. e.*, copper, all the others being less, iron having but one-third as much. The following table gives the metals in their order:

RELATIVE THERMAL CONDUCTIVITY.

AUTHORITY, ROBERTS-AUSTEN.

Silver	100·00
Copper	73·60
Gold	53·20
Sodium	36·50
Magnesium	34·30
*Aluminum	31·33
Zinc	28·10
Cadmium	20·06
Tin	15·20
Iron	11·90
Steel	11·60
Lead	8·50
Platinum	8·40
Antimony	4·03
Bismuth	1·80
Mercury	1·30

*Wiedermann & Franz give for Thermal Conductivity of

Aluminum annealed	38·87
" unannealed	37·96

The importance of the aluminum industry is emphasized by its now supporting a number of papers devoted distinctly and exclusively to its interests.*

Taking the whole field into consideration, as to the uses thus far made and proposed for the metal aluminum, it is my judgment that while there was consumed in the United States only between 600 and 700 tons of aluminum in the year 1896, and while the amount consumed in the present year, 1897, will probably not exceed double that amount of metal, it will probably reach, by the year 1898, at least 2,000 tons per annum, if general business conditions are good.

How greatly this consumption will be exceeded in the year 1900 can hardly be conjectured. As a random guess (which, however, is based upon a considerable study of the situation), I will estimate the consumption of aluminum in the United States for the year 1900 at 10,000 tons.

This estimate, I am aware, is sadly below the roseate estimates of the early writers upon aluminum. Especially is it under the prospects held forth in the many forms of prospectus of would-be inventors of aluminum processes. Still, as a practical manufacturer of aluminum upon a commercial scale, and in touch to a considerable extent with the present development of the uses of aluminum in the arts, from all information which I have in the matter, I will consider the circumstance a most fortunate one if the estimate of 10,000 tons of aluminum as the consumption of the United States in the year 1900 should be verified.

*In this country the *Aluminum World* is published at 14 Lafayette Place, New York City. In France, *L'Aluminium*, 26 Rue Brunnel, Paris, and *L'Electrochimie*, Review of the Science and of the Industry of Aluminium, 37 Rue de Berne, Paris. In Great Britain, *Aluminum and Electrolysis*, 1 Crosskey Sq., E. C. Little, Britain, London.

PISTON PACKING RINGS OF MODERN STEAM ENGINES.

By Otto C. Reymann,
With Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

[*Concluded from vol. cxliv, p. 126.*]

The bending moment M was found to be variable, its value depending upon angle α. As the Ramsbottom ring is of a uniform cross-section, I is constant and also r and E. Consequently the radius of curvature ρ must be variable in order to fulfil equation (7). Introducing

$$I = \frac{h\,t^3}{12}$$

and from equation (4) $M = p\,r^2\,h\,(1 - \cos\alpha)$ equation (7) is written:

$$\frac{1}{\rho} = \frac{1}{r} - \frac{12\,p\,r^2\,(1 - \cos\alpha)}{E\,t^3} \qquad \text{(B)}$$

and for

TABLE 2.

α	$\frac{1}{\rho} =$	$\rho =$	$p =$
0°	$\frac{1}{r}$	$\rho = r$	$= 0$
90°	$\frac{1}{r} - \frac{12\,p\,r^2}{E\,t^3}$	$\rho_1 = \frac{E\,r\,t^3}{E\,t^3 - 12\,p\,r^3}$	$\frac{E}{12}\left(\frac{t}{r}\right)^3\left(1 - \frac{r}{\rho_1}\right)$
180°	$\frac{1}{r} - \frac{24\,p\,r^2}{E\,t^3}$	$\rho_{max} = \frac{E\,r\,t^3}{E\,t^3 - 24\,p\,r^3}$	$\frac{E}{24}\left(\frac{t}{r}\right)^3\left(1 - \frac{r}{\rho_{max}}\right)$
270°	$\frac{1}{r} - \frac{12\,p\,r^2}{E\,t^3}$	$\rho_1 = \frac{E\,r\,t^3}{E\,t^3 - 12\,p\,r^3}$	$\frac{E}{12}\left(\frac{t}{r}\right)^3\left(1 - \frac{r}{\rho_1}\right)$
360°	$\frac{1}{r}$	$\rho = r$	0

The values for ρ compiled in this table are calculated with the ring pressure p taken constant around the whole ring; the last column may be used in finding the pressure p exerted by the packing ring, if the radius of curvature ρ is known.

Example No. 1.—Ramsbottom packing rings are frequently used in locomotive engines. Here usually the rings have to carry a part of the piston weight, and, consequently, are more rapidly worn on their lower half than on their upper half. By having them fit loosely in their grooves, the vibration of the engine causes the rings to slowly move around, thus bringing each element of the ring surface by and by to the points of greatest pressure. This equalizes the wear greatly, and a uniform distribution of the pressure almost over the whole circumference of the packing ring is the result. Rings of uniform cross section are, therefore, used on locomotive pistons. Let us suppose we have a cast-iron packing ring of ½ x ¾ inch cross section for an 18½-inch steam cylinder. Then $r = 9¼$ inches, $h = ½$ inch, $t = ¾$ inch. If this ring shall exert a $p = 6½$ pounds, the greatest stress opposite the cut at point D is according to equation (A),

$$f = 12 . 6½ . \left(\frac{9¼}{¾}\right)^2 = 11{,}865 \text{ pounds per square inch.}$$

or about one-fourth of the breaking stress, assuming a material similar to that tested by Mr. Vogt. Then with $E = 13{,}300{,}000$, the radii of curvature necessary to produce a pressure of 6½ pounds per square inch are found by equation B to be at point D.

$$\rho_{max} = \frac{13{,}300{,}000 . 9¼ . (¾)^3}{13{,}300{,}000 . (¾)^3 - 24 . 6½ . (9¼)^3} = 9.46''$$

and at C or E:

$$\rho = \frac{13{,}300{,}000 . 9¼ . (¾)^3}{13{,}300{,}000 . (¾)^3 - 12 . 6½ . (9¼)^3} = 9'35''$$

As ρ_{max} differs only little from ρ, the cylinder from which the rings are cut off may be turned 18'92 inches in diameter, and the proper curvature at point C or E can then easily be obtained by filing off the ends of the ring after it has been cut.

V. *Ring of Variable Thickness.*—Discussing equation (7)

$$E I \left(\frac{1}{r} - \frac{1}{\rho}\right)$$

it was said that M was variable and that therefore at least one factor on the other side of the equation must be variable, too, in order to fulfil the equation for any value of α. E and r are always constant, no matter what type of ring is selected. However, ρ and I depend entirely upon the shape of the packing ring. Hence, either or both can be variable at the same time.

If the outside of the ring is made into a circle: ρ = constant and then

$$I = \frac{M}{E \left(\frac{1}{r} - \frac{1}{\rho}\right)}$$

For a rectangular cross-section we have

$$I = \frac{t^3 h}{12}$$

and therefore

$$t = \sqrt[3]{\frac{12\,M}{E.h.\left(\frac{1}{r} - \frac{1}{\rho}\right)}} \tag{8}$$

Substituting for M its value, we get for a cross-section at C or E (*Fig.* 5):

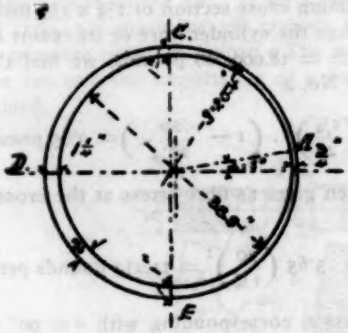


FIG. 5.

$$t_1 = r\sqrt[3]{\frac{12\,p}{E}\,\frac{1}{1 - \frac{r}{\rho}}} \tag{C}$$

and as maximum thickness at point (D)

$$t_{max} = 2r\sqrt[3]{\frac{3\,p}{E}\,\frac{1}{1 - \frac{r}{\rho}}} \tag{D}$$

Combining equations (8) and (D) we get the ratio

$$\frac{t}{t_{max}} = \sqrt[3]{\frac{1 - \cos\alpha}{2}} = \sqrt[3]{\sin^3\frac{\alpha}{2}}$$

After t_{max} is determined the thickness for any cross-section may be taken from Table (3):

TABLE No. 3.

a	$t =$	a	$t =$
10° or 350°	·197 t_{max}	120° or 240°	·909 t_{max}
15° " 345°	·257 "	135° " 225°	·948 "
30° " 330°	·406 "	150° " 210°	·977 "
45° " 315°	·527 "	165° " 195°	·994 "
60° " 300°	·630 "	180°	1·000 "
90° " 270°	·794 "		

Example No. 2.—Let the cylinder bore be 40 inches. A cast-iron packing ring, having a maximum cross section of 1¼ x 1¼ inches, is turned ·02 x 40 larger in diameter than the cylinder bore or its radius of curvature $\rho = 20{\cdot}4$ inches. Assuming $E = 18{,}000{,}000$ pounds, we find the pressure produced by this ring in table No. 2

$$p_{180^\circ} = \frac{18{,}000{,}000}{24}\left(\frac{1\frac{1}{4}}{20}\right)^3 \cdot \left(1 - \frac{20}{20{\cdot}4}\right) = 3{\cdot}65 \text{ pounds per square inch.}$$

Equation (A) then gives as fibre stress at the cross section opposite the cut

$$f_{max} = 12 \cdot 3{\cdot}65 \left(\frac{20}{1\frac{1}{4}}\right)^2 = 11{,}213 \text{ pounds per square inch.}$$

The ring thickness t_1 corresponding with $a = 90°$ or 270° follows from table No. 3;

$$t_1 = {\cdot}794 \cdot 1\tfrac{1}{4} = {\cdot}9925 \text{ inch, say } t_1 = 1 \text{ inch,}$$

and the intensity of stress at this cross section

$$f = 6 \cdot 3{\cdot}65 \cdot \left(\frac{20}{1}\right) = 8{,}760 \text{ pounds per sqare inch.}$$

According to table No. 3, theoretically a thickness equal to zero would be required for each end of the ring, if only the condition—the pressure exercised by the packing ring shall be uniform—were to be fulfilled. The necessity of maintaining a steam-tight joint, however, fixes the smallest thickness of the ring at ¾ inch. Consequently, p can only be constant for the middle of the circumference and increases towards the two ends at the cut.

If we lay out the ring according to the thickness calculated for each cross section from the above table, we find that a circle of 38·8 inches diameter fits the theoretical curve approximately. The pressure now obtained at point A ($a = 5°$) amounts to (equation B)

$$p = \frac{E}{12}\left(\frac{t}{r}\right)^3 \left(\frac{1 - \frac{r}{\rho}}{1 - \cos a}\right) = \frac{18{,}000{,}000}{12}\left(\frac{3}{4}\right)^3 \left(\frac{1 - \frac{20}{20{\cdot}4}}{1 - \cos 5}\right) = 395{\cdot}5 \text{ lbs.}$$

and gradually decreases as shown by table (4)

TABLE NO. 4.

a	t	p	a	t	p
5°	¾"	395·5 lbs.	45°	⅛"	6·8 lbs.
10°	¼"	105·45 "	60°	⅛"	5·02 "
20°	⅛"	26·37 "	90°	⅛"	3·75 "
30°	⅛"	13·3 "			

Although these values are only approximate, as the formulæ used were derived under the assumption that p is constant for the whole circumference, they give sufficient evidence why this type of packing ring bears so much harder on the extreme points at the cut. If we reduce $t_0°$ from ¾ to ⅝ inch, that is only ⅛ inch, $p_0°$ would be 228 pounds, and only little more than one-half of the pressure obtained before. The advantage of tapering the rings toward the cut and the importance of a loose fit for this type can be easily recognized.

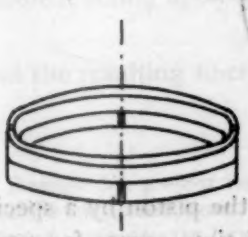


FIG. 6.

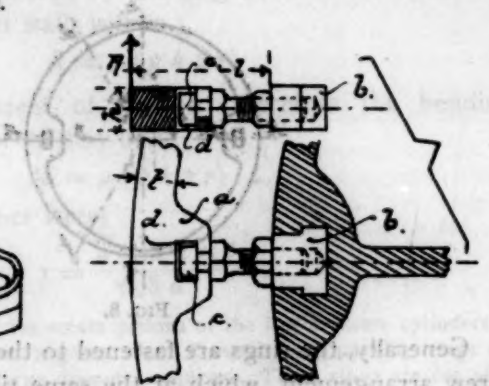


FIG. 7.

VI. *The Crescent Type Packing Ring.*—The examples given in the foregoing chapters show the importance of machining the rings to their correct theoretical shape. In the Crescent type packing ring this is greatly facilitated as its inner surface does not require any machining at all, but is left rough. The length of the circumference is one-half of a full circle, corresponding with $a_{max} = 180°$. Otherwise this type is very similar to the ring treated in the last chapter. The breadth being uniform, the thickness of the cross-section gradually decreases towards the ends. Since the length of the circumference is only $= r\pi$, two rings must be placed in the same plane, making a total of four rings for one set. As a piston generally

carries two sets of packing rings a groove of four times the breadth of one packing ring must be turned in the circumference of the piston block. In order to prevent undue leakage of steam the peculiar shape of the Crescent type necessitates the fastening of each ring to the piston block. Not only that there is some clearance between the rings lying in the same plane, but just near their ends they are not in good contact with the cylinder, the deviation of the actual from the theoretical curvature reaching its maximum at these points. The two other rings belonging to the same set, then must be placed in such a way as to break joint (*Fig. 6*), and, of course, the relative position of the four rings must always remain the same.

FIG. 8.

Generally, the rings are fastened to the piston by a special screw arrangement, which at the same time serves for readjusting the ring pressure. The ring carries at its heaviest part a boss (*a*) (*Fig. 7*), into which the head of a stay bolt is fitted. A wrought-iron T-shaped piece (*b*), serving as a nut for the threaded end of the stay bolt, is inserted into the piston. The head (*c*) can freely turn in the recess (*d*) and thus the ring will be moved away from or toward the center by turning the stay-bolt secured in its position by a lock nut. Besides taking up the reaction of the ring pressure, the stay bolt has to guide the packing ring. This latter purpose requires a rigid connection, and frequent readjustments as the ring wears off are indispensable for retaining the piston in good working order. Considering that the ring is supported only at one point and here rigidly, the free play of the spring action of its central part is

considerably handicapped. Besides this, as four of these rings are required for each set, there are eight points of excessive pressure against only two, if a split ring, as treated in the fifth chapter, is employed.

The maximum bending moment is found at cross-section *A B, Fig. 8,* where

$$a = 90°$$

then from Table No .1

$$M_{max} = p\, r^2\, h \qquad (9)$$

and hence the greatest tensile stress in the ring

$$f_{max} = 6\, p \left(\frac{r}{t}\right)^2$$

The friction produced by the ring between its circumference and the cylinder walls will be

$$R = \mu\,(p\, h\, 2\, r)$$

where μ = coëfficient of friction; therefore the bending moment acting upon the stay bolt

$$M = \mu\,(p\, h\, 2\, r)\,.\, l$$

and the resulting fiber stress

$$s = \frac{\mu\,(p\, h\, 2\, r)\, l}{.098\, d^3}$$

Example No. 3.—For the steam pistons of the low-pressure cylinders in multiple expansion steam engines, often Crescent type packing rings are selected, owing to the large diameter required. These rings are cut off a cast cylinder of such a cross section as to make two rings at each cut, after they are severed at *c* and *e (Fig. 8).* This method has the advantage that the outside of each ring can be finished accurately, whereas a correct curvature of its inner surface is easily obtained by shaping the pattern properly. Turning the whole cylinder to proper size is all the machining necessary. The cross-section of the packing ring may decrease from 1¾ x 1¾ inches to 1 x 1¾ inches, the bore of the steam cylinder may be 7 foot, or $r = 42$ inches. If the ring shall produce a $p = 3$ pounds per square inch of wearing surface, the tensile stress will become

$$f_{max} = 6\,.\,3 \left(\frac{42}{1\tfrac{3}{4}}\right)^2 = 10{,}368 \text{ pounds per square inch.}$$

The outside diameter to which the cast-iron cylinder has to be finished before the rings are cut off is calculated from table No. 2.

$$\rho_{max} = \frac{E\, r\, t^3}{E\, t^3 - 12\, p\, r^3} = \frac{18{,}000{,}000\,.\,42\,(1\tfrac{3}{4})^3}{18{,}000{,}000\,.\,(1\tfrac{3}{4})^3 - 12\,.\,3\,.\,42^3} = 43.17 \text{ inches,}$$

In order to lay out the inside curve, the ratio of the ring thickness t at any cross-section to t_{max} may be determined at first. Substituting equation (9) in equation (8) and combining both with equation (4), we find in a similar manner, as shown in a previous chapter,

$$\frac{t}{t_{max}} = \frac{\sqrt[3]{\frac{12\,p\,r^2\,h\,(1-\cos a)}{E\,.\,h\,.\left(\frac{1}{r}-\frac{1}{\rho}\right)}}}{\sqrt{\frac{12\,p\,r^2\,h}{E\,.\,h\left(\frac{1}{r}-\frac{1}{\rho}\right)}}} = \sqrt[3]{1-\cos a}$$

and for different values of angle a the following:

TABLE NO. 5.

a	$t =$	With $t_{max}=1.75''$ $t =$	a	$t =$	With $t_{max}=1.75''$ $t =$
90°	1.000 t_{max}	1.75″	50°	.71 t_{max}	1.24″
80°	.938 "	1.64″	45°	.664 "	1.16″
70°	.87 "	1.52″	40°	.616 "	1.08″
60°	.794 "	1.39″	35°	.566 "	.99″

In the last column of this table the thickness, at various points, of the packing ring under consideration is given. As the smallest thickness was fixed at 1 inch, the arc $c\,d$ and $e\,f$ will be concentric with the outside curve. The pressure exercised at point g or h amounts to

$$p = \frac{18{,}000{,}000}{42}\left(\frac{1}{42}\right)^3\left(\frac{1-\frac{42}{43.17}}{1-\cos 5°}\right) = 136.6 \text{ pounds per square inch.}$$

VII. *The Double Ring.*—In treating the Crescent type some of its disadvantages were pointed out. The necessity of using four rings for each set in order to obtain a steam-tight joint between piston and cylinder is an undesirable feature. A greater depth of the piston is required, and in turn the weight of the oscillating mass is increased proportionately. Packing rings for large pistons must have a heavy cross-section, and since their breadth is limited by the depth of the piston, their thickness has to be increased.

Now it is obvious that a thin rectangular ring will be more elastic than a thick one of the same material, and if it is proved by practice that rings of a heavy uniform cross-section bear much harder on the extreme points at the cut and are not in contact with the cylinder back of this point, it is only a conse-

quence of the stiffness of the ring at that point. With a thin ring of large diameter, however, we cannot exert the necessary pressure, because the stress at the dangerous cross-section would become too great. According to equation (A)

$$f = 12\,p\left(\frac{r}{t}\right)^2$$

the unit stress increases with the square of $\left(\frac{r}{t}\right)$ *i. e.*, cylinder radius divided by the ring thickness.

A consideration of these facts has led to a design which retains the thin elastic packing ring and yet may be used in large cylinders. This is accomplished by using two concentric rings, *Fig. 9*. The outer ring is proportioned with the object of

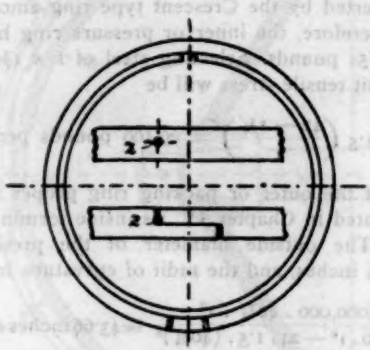


FIG. 9.

obtaining a flexible, uniform wearing ring, which assures a good contact with the cylinder. All the inner ring has to do then is to exercise a pressure upon the outer ring sufficient to prevent leakage of the steam. Steel or any other material of great elasticity may be used for it, as the ring is not in contact with the wearing surface of the cylinder. Cast iron or brass will answer the requirements of the outer ring. Both rings must be split and placed into each other in such a manner as to stagger the cuts, a dowel pin (z) holding the rings in their relative position.

Example No. 4.—In order to fully illustrate the advantages of the double ring over the Crescent type, let us replace the packing ring referred to in example No. 3 by double rings. Instead of eight rings, two double rings of

the same breadth, but lying in separate grooves, are now sufficient, reducing thus the space taken up by the grooves one-half. With the same but constant cross-section 1¾ x 1¾ inches and with the same tensile stress of 10,300 pounds for cast-iron, we get from equation *(A)*:

$$p = \frac{f}{12}\left(\frac{t}{r}\right)^2 = \frac{10{,}300}{12}\left(\frac{1\frac{3}{4}}{42}\right)^2 = 1.49 \text{ pounds per square inch.}$$

The radii of curvature are, according to table No. 2,
for $a = 180°$

$$\rho_{max} = \frac{18{,}000{,}000 \cdot 42 \cdot (1\frac{3}{4})^3}{18{,}000{,}000 \cdot (1\frac{3}{4})^3 - 24 \cdot 1.49 \cdot 42^3} = 43.19 \text{ inches}$$

and for $a = 90°$

$$\rho_1 = \frac{18{,}000{,}000 \cdot 42 \cdot (1\frac{3}{4})^3}{18{,}000{,}000 \cdot (1\frac{3}{4})^3 - 12 \cdot 1.49 \cdot 42^3} = 42.59 \text{ inches}$$

The diameter of the cast cylinder from which the rings are cut off is determined thus by ρ_{max}.

The pressure exerted by the Crescent type ring amounted to 3 pounds per square inch; therefore, the inner or pressure ring has still to produce a $p' = 3 - 1.49 = 1.51$ pounds. Selecting steel of 1 x 1¾ inches cross-section, the greatest unit tensile stress will be

$$f^1_{max} = 12 \cdot 1.5 \left(\frac{42 - 1\frac{3}{4}}{1}\right)^2 = 29{,}160 \text{ pounds per square inch.}$$

The thickness of the outer or packing ring proper is constant, *i. e.*, a parallel ring, as treated in Chapter IV, its inside forming a circle if placed in the cylinder. The outside diameter of the pressure ring is then $84 - 2 \cdot 1\frac{3}{4} = 80\frac{1}{2}$ inches, and the radii of curvature from table No. 2

$$\rho^1_{max} = \frac{30{,}000{,}000 \cdot 40\frac{1}{4} \cdot 1^3}{30{,}000{,}000 \cdot 1^3 - 24 \cdot 1.5 \cdot (40\frac{1}{4})^3} = 43.66 \text{ inches and } \rho^1 = 41.81 \text{ inches}$$

If a cast ring is selected, a ring of variable cross-section (Chapter V) could be employed to advantage. Protected by the outer ring, this ring is not subjected to any wear, and, therefore, its minimum thickness at the cut can safely be reduced to about ¼ inch, giving practically a uniform pressure over its whole circumference.

VIII. *The Non-elastic Packing Ring.*—This type of piston packing ring represents a modification of the double ring. Take a ring of uniform thickness, turned to the same diameter as the cylinder bore, before it is split; then the split ring has no tendency of pressing outward against the cylinder walls; it is "non-elastic;" and the pressure necessary for a steam-tight joint must be produced and exerted upon the ring by some other means. If a second concentric ring, placed inside, is employed for this purpose, we have again a double ring, except

that in this case the outside ring is without tension and does not contribute a share to the total pressure exerted by the combined rings. In cases where the use of a "pressure ring" is found inconvenient, special springs, called packing springs, may be employed instead. These springs, made either of steel or of German silver, are put into the grooves provided for the packing rings and held in place by headless screws or pins. As indicated in *Fig. 10*, the cut in the packing ring is covered by a

FIG. 10.

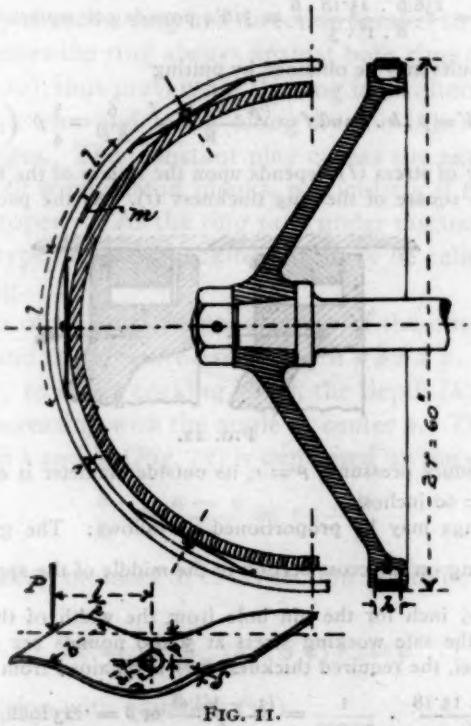


FIG. 11.

plate (*M*) fastened on the inside in such a way that no steam can pass from one side of the piston to the other.

Example No. 5.—A 60-inch piston, shown in *Fig. 10*, is fitted with a cast-iron non-elastic packing ring carried by six packing springs *(Fig. 11)*. The ring of a uniform cross-section 1 inch thick and 3 inches wide represents a continuous beam, supported at twelve points

$$\frac{(60 - 2 \cdot 1)}{12} \pi = 15{\cdot}18 \text{ inches apart.}$$

Let us assume that a pressure of 3 pounds per square inch is required for a steam-tight joint; then each end of a spring must exert a force of $3 \times 3 \times 15{\cdot}18 = 136{\cdot}6$ pounds upon the ring. The stresses caused in the packing ring by these twelve single loads, which the elasticity of the ring must uniformly distribute over the whole circumference, can be computed with the well-known formulæ for a beam fixed at its ends and loaded at center. The maximum bending moment is

$$M_{max} = \frac{W\,l}{8} = \frac{h\,t^2}{6}\,f$$

and the resulting intensity of stress in the packing ring

$$f = \frac{136{\cdot}6\,.\,15{\cdot}18\,.\,6}{8\,.\,1^2\,.\,3} = 518{\cdot}4 \text{ pounds per square inch.}$$

The same results may be obtained by putting

$$W = p\,.\,h\,.\,l \text{ and } f = \frac{(p\,.\,h\,.\,l)\,.\,l}{8}\,.\,\frac{6}{h\,t^2} = \frac{3}{4}\,p\,\left(\frac{l}{t}\right)^2$$

The intensity of stress (f) depends upon the square of the free span (l) divided by the square of the ring thickness (t). As the packing ring itself

FIG. 12.

shall not produce pressure: $\rho = r$, its outside diameter is equal to the cylinder bore = 60 inches.

The springs may be proportioned as follows: The greatest bending moment acting on the cross section in the middle of the spring is $\frac{P\,l}{2}$

Deducting ½ inch for the pin hole from the width of the cross section and taking the safe working stress at 50,000 pounds per square inch for hardened steel, the required thickness (δ) is obtained from

$$\frac{136{\cdot}6\,.\,15{\cdot}18}{2}\,.\,\frac{1}{50{,}000} = \frac{(3 - \tfrac{1}{2})\,\delta^2}{6} \text{ or } \delta = {\cdot}223 \text{ inch, say } \tfrac{1}{4} \text{ inch.}$$

The ordinate at center of the unstrained spring must be

$$\varphi = \frac{6\,\left(\frac{l}{2}\right)^3}{b\,\delta^3}\,.\,\frac{P}{E} = \frac{6\,.\,(7{\cdot}59)^3}{3\,.\,(\tfrac{1}{4})^3}\,.\,\frac{136{\cdot}6}{30{,}000{,}000} = {\cdot}254 \text{ inch}$$

in order to produce the required pressure of 136·6 pounds.

IX. *The Spiral Packing Ring.*—The packing rings treated so far formed either a complete circle or a section of it, and

accordingly the angle at center a varied either from 0° to 360° or from 0° to 180°, as, for instance, in the Crescent type. For reasons discussed above, all these rings must be cut open, making special devices necessary for stopping the leakage of steam through this cut and necessitating the provision of at least two sets of packing rings. If we connected several individual rings so as to form one continuous ring of as many coils, no cuts would be required. Another advantage especially valuable in engines with high piston speeds is offered by the elasticity of such a ring in a direction parallel to the cylinder axis. It presses the ring always against both rims of the piston block (*Fig. 12*), thus preventing the ring from alternately being lifted off one rim and taken along by the other one as the stroke changes. This constant play causes the excessive wear of the rims of some piston blocks, particularly if the rings are not fitted properly. As the ring now under discussion forms a spiral, this type of piston packing ring may be called the spiral packing ring.

The area of an infinitesimal element of the outer surface is $= h.\, r\, d\, \varphi$, and the pressure exerted by it $p\, h\, r\, d\, \varphi$. (*Fig. 13*).

Contrary to other packing rings, the depth (h) is not constant, but increasing with the angle at center a. Then the relation between h and h_1 (*Fig. 13*) is expressed by the equation

$$\frac{h_1}{h} = \frac{a - \varphi}{a} = 1 - \frac{\varphi}{a} \qquad (10)$$

The bending moment at cross-section B will be

$$M = p \int_0^a (h_1 r\, d\, \varphi)\, r \sin \varphi$$

or in connection with equation (10)

$$M = p\, h\, r^2 \int_0^a \left(1 - \frac{\varphi}{a}\right) \sin \varphi\, d\, \varphi$$

$$= p\, h\, r^2 \left\{ 1 - \cos a - \frac{1}{a} \int_0^a \varphi \sin \varphi\, d\, \varphi \right\}$$

$$= p\, h\, r^2 \left\{ 1 - \frac{\sin a}{a} \right\} \qquad (E)$$

At point B the cross-section is $= h \cdot t$, consequently the intensity of stress

$$f = 6\,p\,\left(\frac{r}{t}\right)^2\left(1 - \frac{\sin a}{a}\right)$$

an equation similar in form to that derived for the Ramsbottom ring.

After the first coil is completed and (h) has grown from zero (corresponding with $a = o$) to $h = b\,(a = 2\,\pi)$ the depth

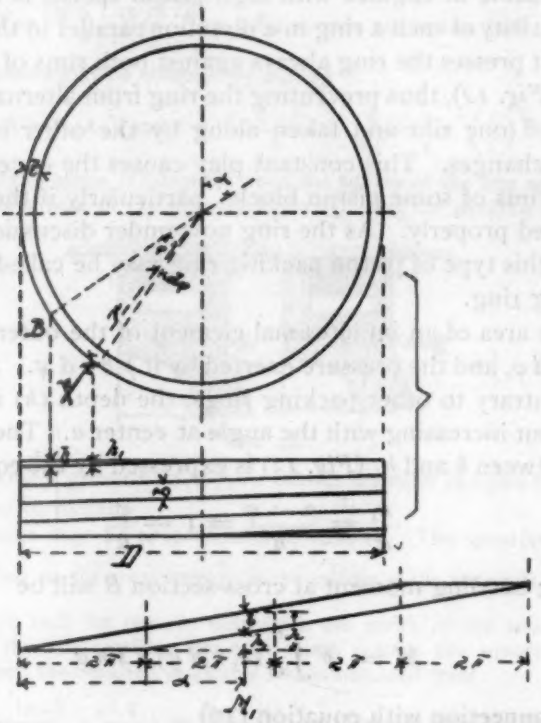


FIG. 13.

of the following coils is constant $= b$, until the last coil is reached for which the same relations hold good as for the first, h decreasing from b to zero. Equation (E) is therefore only good for these two coils, *i. e.*, between the limits

$$a = 0 \text{ and } a = 2\pi$$

From the accompanying figure it will be readily seen that all coils of uniform depth can be taken as difference be-

tween two coils of increasing depth which are rotated upon each other 360°. The bending moment acting on the second and following coils is then expressed by

$$M_1 = p\,r^2 \left\{ h\left(1 - \frac{\sin a}{a}\right) - h_1\left(1 - \frac{\sin a}{a - 2\pi}\right) \right\}$$

or considering that

$$h - h_1 = b \text{ and } \frac{h_1}{b} = \frac{2\pi + a}{2\pi}$$

$$M_1 = p\,r^2\,b\left(1 - \frac{\sin a}{a}\right)\left(\frac{4\pi}{2\pi - a}\right) \qquad \text{(F)}$$

The radii of curvature of the various coils are derived from the corresponding bending moments in a similar manner, as shown in Chapter IV. The relation between M_1 and ρ is expressed by equation (7)

$$M = E.I\left(\frac{1}{r} - \frac{1}{\rho}\right)$$

where

$$I = \frac{b\,t^3}{12}$$

for a rectangular cross-section, t being constant for the whole ring.

The following table contains values of M_1 f and ρ for different cross-sections fixed by the angle at center a. It will be noticed that the bending moment for

$$a = \pi,\ 2\pi,\ 3\pi \ldots$$

is constant; it can be taken as an average value

a	$M =$	$f =$	$\rho =$	a	$M =$	$f =$	$\rho =$
$\frac{\pi}{2}$	$.36\,p\,r^2\,h$	$2.16\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 4.32\,p\left(\frac{r}{t}\right)^2}$	$\frac{5}{2}\pi$	$2.02\,p\,r^2\,b$	$12.12\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 24.24\,p\left(\frac{r}{t}\right)^2}$
π	$p\,r^2\,h$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^2}$	3π	$p\,r^2\,b$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^2}$
$\frac{3\pi}{2}$	$1.21\,p\,r^2\,h$	$7.26\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 14.52\,p\left(\frac{r}{t}\right)^2}$	$\frac{7}{2}\pi$	$.759\,p\,r^2\,b$	$4.55\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 9.1\,p\left(\frac{r}{t}\right)^2}$
2π	$p\,r^2\,b$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^2}$	4π	$p\,r^2\,b$	$6\,p\left(\frac{r}{t}\right)^2$	$\frac{r\,E}{E - 12\,p\left(\frac{r}{t}\right)^2}$

Example No. 6.—The spiral packing ring, shown in *Fig. 13*, shall fit a steam cylinder of 40-inch bore. It consists of four coils, and, if compressed, has a depth of $3 \cdot \frac{3}{4} = 2\frac{1}{4}$ inches. The cast-iron ring shall be so proportioned as to exert a pressure of 3 pounds per square inch, the average tensile strength (f) not exceeding 7,500 pounds per square inch. The cylinder from which the packing ring will be made by cutting a spiral groove into it must be turned inside and outside concentric, the required thickness being 1 inch, according to

$$7200 = 6 \cdot 3 \left(\frac{20}{t}\right)^2$$

from table (6) as radius of curvature

$$\rho = \frac{20 \cdot 18{,}000{,}000}{18{,}000{,}000 - 12 \cdot 3 \cdot \left(\frac{20}{1}\right)^3} = 20{\cdot}33 \text{ inches.}$$

The greatest tensile stress is reached at $\alpha = \frac{5\pi}{2}$ where

$$f_{max} = 12 \cdot 12 \cdot 3 \cdot \left(\frac{20}{1}\right)^2 = 14{,}500 \text{ pounds per square inch}$$

and the corresponding radius:

$$\rho_{max} = \frac{20 \cdot 18{,}000{,}000}{18{,}000{,}000 - 24 \cdot 24 \cdot 3 \cdot \left(\frac{20}{1}\right)^3} = 20{\cdot}66 \text{ inches.}$$

The clearance between the coils may have been made so large that the ring can be compressed 3 inches ($= \lambda$) until it is closed. If its outside diameter thereby is 40 inches, the force P, which must be applied, and with which the ring afterward presses against the rims of the piston block, can be computed with the formulæ for helical springs of rectangular cross section. It is

$$P = \frac{\lambda}{n} \frac{G}{3(b^2 + t^2)} \left(\frac{b\,t}{D}\right)^3 = \frac{3}{2} \frac{7{,}000{,}000}{3 \cdot 1{\cdot}56} \left(\frac{\frac{1}{4}}{40}\right)^3 = 14{\cdot}8 \text{ pounds.}$$

where λ the total compression of the ring,

n the effective number of coils,

D outside diameter of compressed spring,

G modulus of shearing elasticity.

The resulting stress due to torsion is found to be

$$f_1 = \frac{9}{4} \frac{P}{b^2 t} \frac{D}{} = \frac{9 \cdot 14{\cdot}8 \cdot 40}{4\,(\frac{1}{4})^3} = 2{,}368 \text{ pounds per square inch.}$$

MOTOR ROAD VEHICLES.

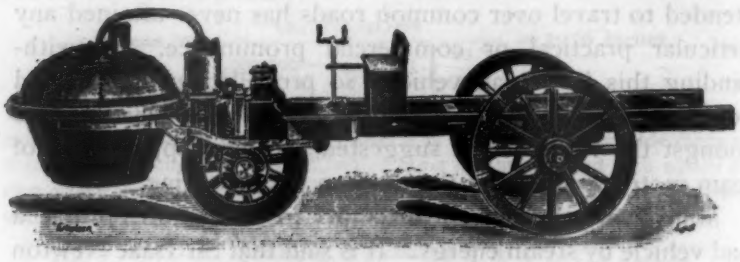
By Joseph Sachs.

Historical.—Modern traveling facilities over fixed land routes have certainly reached a high degree of perfection. Every improvement in motive powers, conveyances and roadbeds is tried with a view to further increasing the safety, economical operation, speed, luxury and comfort of such conveying systems, until we almost feel that additional development, except in speed, would be excessive. In striking contrast, however, therewith, are our present modes of conveyance over ordinary roads. Here muscular power still reigns supreme, as it did ages ago; and while mechanical motive powers seem to find almost universal application in displacing animal energy, yet their utilization for the propulsion of vehicles intended to travel over common roads has never attained any particular practical or commercial prominence. Notwithstanding this fact, road vehicles so propelled even preceded the railroad locomotive. Steam-propelled road vehicles were amongst the very earliest suggested uses and applications of steam motive power and the modern steam engine.

Many were the pioneer attempts to successfully propel a road vehicle by steam energy. It is said that Sir Isaac Newton proposed a wheeled carriage which was moved forward by the reacting effect of a rearwardly directed steam jet issuing from a crude steam kettle on the vehicle. Joseph Cugnot, an officer in the French army, is however credited with having built the first really operative steam-propelled vehicle in 1769. Cugnot's motor vehicle had three wheels, the boiler and reciprocating piston engine being mounted on the front steering wheel, which was driven by a rachet gear. Following Cugnot's experiment came many others, amongst whom were Evans, in America, and Murdock, Symington and Trevithick, in England, who devised various more or less successful conveyances, propelled in most instances by reciprocating steam engines. Crude construction of engines and boilers and the meager information available on the subject was strongly

apparent in these pioneer attempts. Many doubted the propelling ability of ordinary round wheels when turned by a self-contained motive power, and therefore devised vehicles which were propelled by means of rotating radial feet or arms, or pushed by means of rearwardly projected levers.

Many successful steam vehicles were, however, built and used, particularly in England. Active development was probably hindered by the rapid advancement of the steam railroad, and the enactment of certain English laws relating to the operation of such road vehicles almost stopped further progress in this direction as far as that country was concerned. The development of the motor-propelled road vehicle from then on was in the direction of large, slow-moving, hauling steam-road locomotives, which were used principally for agricultural purposes. Until within recent years these were the



Cugnot's steam road vehicle.

only successful and commercial motor road vehicles. Lighter and more rapid vehicles, intended to act as carriers as well, also appeared at various times. The development of the gas engine, electric motor and other light portable motive powers was a particularly important step in the advancement of self-propelled road vehicles of this type.

It is unnecessary to speak of the development of the motor carriage or vehicle, other than the road locomotive, in Europe during the last decade. The various races and "meets," beginning in France in 1891, and followed by many others in this country and elsewhere, are also well known. Undoubtedly the time has now arrived when the problem must be attacked with the firm attempt to solve it in the near future. The tend-

ency towards increased speed and economy in industrial and commercial directions undoubtedly demands a substitute for animal propulsion, and there are certainly a multitude of other reasons which recommend the mechanically propelled road vehicle for all other purposes.

Although the ideal motive power for this purpose is perhaps not yet available, many promising vehicles have been produced, including two-, three- and four-wheeled conveyances. While the problem depends greatly on the perfected portable motive power, yet it also involves many other important considerations. Some general features which need consideration are here presented. Light three- and four-wheeled vehicles, similar to various well-known types intended for the conveyance of goods or passengers, are particularly considered. Such mechanically-propelled vehicles must be considered from a radically different point of view than the horse-drawn conveyance, not only concerning the mode of propulsion, but also various other elements which are necessitated thereby.

The Motor.—Various portable motor powers are available, including steam, gas and electric motors and their various modifications. All of these have been practically applied, and motor vehicles at the present time may best be divided into these three classes. There are also other motors which have been experimentally tried for this purpose, but the results obtained with them have not been sufficiently successful to warrant serious consideration as yet, although some of them give promise of future success. Undoubtedly the selection of a motive power must depend greatly upon the use for which the vehicle is intended. While each form of motive power has certain inherent features, requiring special contrivances for its application, a motor for this purpose should meet certain general requirements.

The size and capacity of the motor necessary to propel a certain vehicle depend greatly upon the type adopted. Where the motor is capable of self-starting, speed changes and reversal, its connection to the driving wheels will be far simpler than where these features must be obtained by mechanism exterior thereto. In the former case, the motor may be of a

smaller capacity than in the latter, where complicated gearing decreases the efficiency of transmission. The flexibility of the motive power adopted also affects the size of the motor required. A motor capable of exerting several times its rated capacity for short intervals has certainly a decided advantage over one which is easily stalled by an overload. In the latter case a motor larger than necessary to meet the ordinary requirements would be needed, owing to the necessity for sufficient capacity to meet sudden excess demands. Excessive capacity, however, in order to enable the vehicle to travel at extreme speed or to climb grades at maximum speed, is, however, to be discouraged. Aside from the danger involved in traveling in a self-propelled vehicle operated at unreasonable speed, the larger motor required would probably increase the cost and decrease the efficiency of operation under ordinary conditions. The motor should be capable of sudden spurts of power, yet it should always work, under average conditions, at as near its maximum load point as possible. American practice has been to use a gas engine of about 4 to 5 horsepower to propel a light carriage with from two to four passengers, at a fairly high speed. European carriages employ a somewhat smaller motor, which is permissible in view of the particular excellence of the roads. A smaller electric motor will in most cases propel a similar vehicle. Electric motors of about 3 horse-power normal capacity have been adopted in several successful vehicles.

Whatever form of motor is adopted, the conditions necessarily demand that it should be compact, give a maximum amount of energy with the least possible weight, be unaffected by the weather or hard usage, and entirely self-maintaining and automatic in its action. It must also be free from noise, odor and serious vibration, and the necessary fuel, whether coal, oil or the elements of electro-chemical change, must be cheap and readily procurable. If a reciprocating motor is used, the vibration will greatly depend upon its proper location and support, but primarily the reciprocating action should be balanced. The impulse of the pistons should also be cushioned and directed so as to least affect the spring-supported vehicle body.

Rotary motors, certainly, have great advantages over the reciprocating form.

Whether one or two separate motors are to be used is a matter depending greatly on the motive power selected. Double motors, separately operated, cost and weigh more, are less efficient than a single motor, and have advantages only when the motor is capable of self-starting, reversing and speed changes. With such motors, one connected separately to each driver will result in certain advantages which will be apparent when the gearing and steering mechanism is discussed. Where, however, the motor does not possess such features, their duplication is not to be advised.

Vehicle Frame and Body and Disposition of Mechanism.—Rapid traveling over uneven roads and the stresses and strains due to a self-contained motive power, driving traction wheels, necessitate not only a strong, although light construction, but also one which is particularly adapted to traction work. In some instances the motor and other mechanism have been placed in the vehicle body, which has been directly fitted with axles and wheels, to which the motor is suitably geared. In others a separate vehicle truck has been adopted, on which all driving apparatus is mounted, and which can be fitted with any suitable form of body. The latter construction seems to possess advantages. In the construction of such trucks tubular steel framing seems to have been generally adopted, although angle bars have also been used.

Neither the feather-weight nor the battering-ram type of construction will meet with approval. A motor vehicle is intended for ordinary usage. It is neither expected to resist the unusual accident nor to be adapted for traveling only over asphalt-paved avenues. The development of the bicycle has undoubtedly demonstrated the correct position on this point.

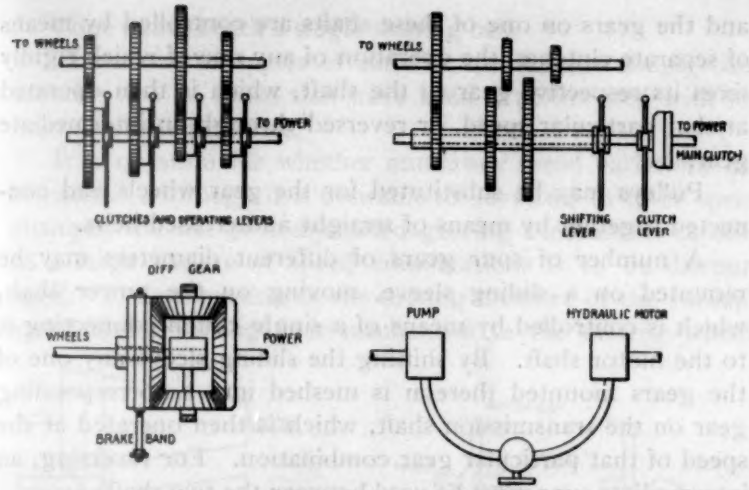
Whether the motor and mechanism is located in the body of the vehicle or directly mounted on a separate truck, its disposition (and also of the load to be carried) must be such as to produce not only tractive effect, but also to prevent top-heaviness. Safety in a vehicle moving at a rapid speed over rough roads and steered around sharp curves can only be

secured by having the center of gravity of the entire loaded vehicle as low as possible. To produce the best tractive effects, it is certainly essential to properly weight the driving wheels, yet in many instances this point seems to have been more or less ignored. The location of the motor and mechanism over the steering wheels may not only prevent the operation of the drivers without slipping, but also increases the difficulty of steering. A proper relation should exist between the capacity of the motor and the tractive ability of the driving wheels. A motor having more energy than can be efficiently converted into vehicle travel by the drivers is a poor contrivance.

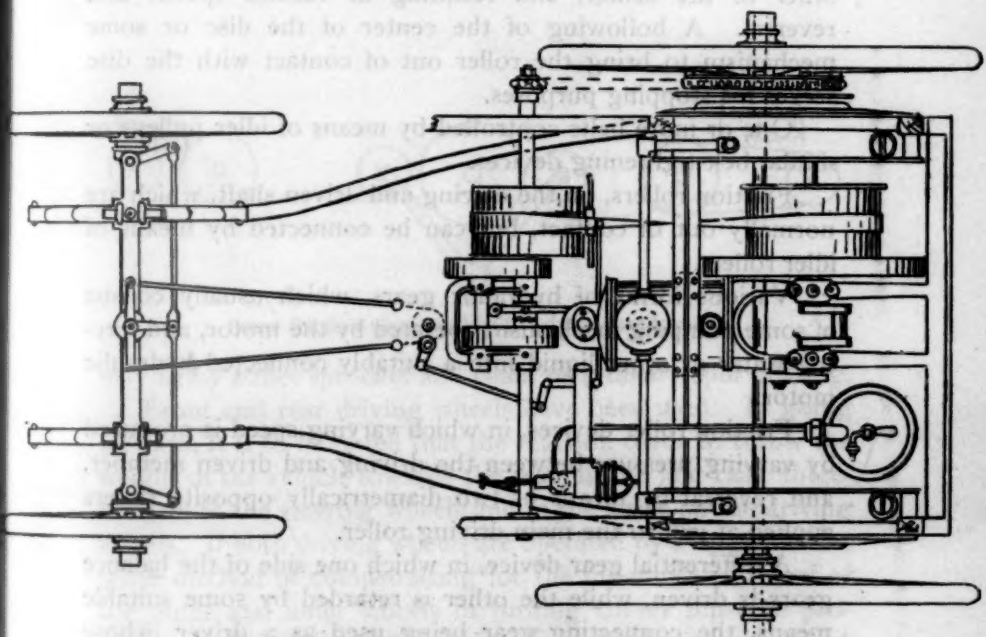
Gearing.—The simplest form of connecting the motor to the driving wheels is possible where the motor is inherently capable of self-starting in either direction and speed variations. With such motors the moving member would in its simplest form be directly connected to the driving wheels or axles. As this, however, is difficult of accomplishment, even with such motors, some simple form of gearing has been used, consisting of either an ordinary spur gear or sprocket wheel and chain connection. In such instances the gearing is but a minor consideration, consisting generally of but a single reduction, and whose efficiency, when properly constructed, is comparatively high. Where, however, the motor is incapable of inherently performing the functions above mentioned, the gearing between the motor and the driving wheels bears a most important relation to the motor, as it is this part of the mechanism which must be relied upon for this purpose. Innumerable arrangements of mechanical devices have been devised to serve as variable speed and reversing gears. It is a matter of great difficulty to eliminate complication and serious inefficiency from such mechanism. The larger capacity needed in the motors requiring such gears is largely due to the inefficiency of transmission.

Various devices have been used to produce the above-mentioned results, among which the following may be mentioned:

The transmission shaft is fitted with a number of spur gears which coact with corresponding gears on the driving shaft from the motor. Each of these gear sets is differently speeded,



Some variable-speed gears.



Plan of a German gasoline motor vehicle with shifting belt transmission.

and the gears on one of these shafts are controlled by means of separate clutches, the operation of any one of which rigidly fixes its respective gear to the shaft, which is then operated at that particular speed, or reversed through an intermediate gear.

Pulleys may be substituted for the gear wheels and connected together by means of straight and crossed belts.

A number of spur gears of different diameters may be mounted on a sliding sleeve, moving on the power shaft, which is controlled by means of a single clutch connecting it to the motor shaft. By shifting the sliding sleeve any one of the gears mounted thereon is meshed into a corresponding gear on the transmission shaft, which is then operated at the speed of that particular gear combination. For reversing, an intermediate gear must be used between the two shafts.

A friction disc, over whose surface a small friction roller, sliding on a keyed shaft, is moved radially to one side or the other of the center, and resulting in various speeds and reversal. A hollowing of the center of the disc or some mechanism to bring the roller out of contact with the disc serves for stopping purposes.

One or more belts controlled by means of idler pulleys or similar belt-tightening devices.

Friction rollers, on the driving and driven shaft, which are normally out of contact, but can be connected by means of idler rollers.

Various forms of hydraulic gears, which usually consist of some pumping mechanism operated by the motor, and forcing water or other liquid into a suitably connected hydraulic motor.

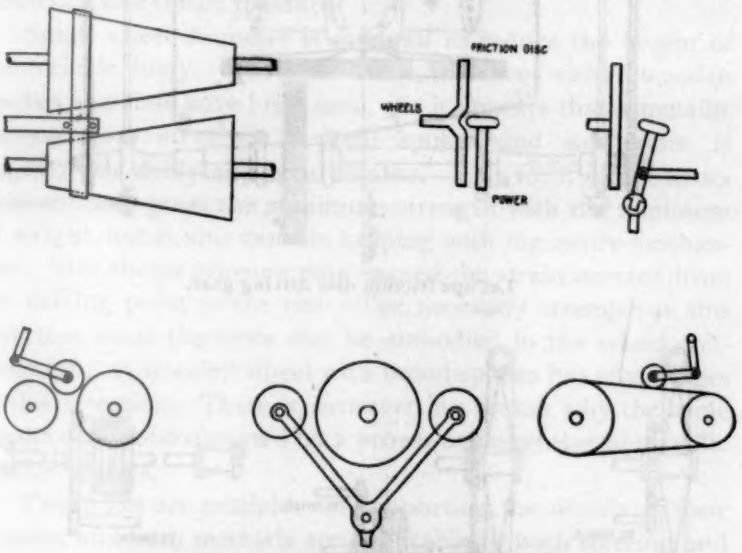
Friction roller devices, in which varying speed is produced by varying pressure between the driving and driven member, and reversal by means of two diametrically opposite rollers applied at will to the main driving roller.

A differential gear device, in which one side of the balance gears is driven, while the other is retarded by some suitable means, the connecting gear being used as a driver, whose speed is varied by varying the retarding force.

Cone pulleys with a single shifting belt.

The above examples of variable speed gears simply constitute a few of those that have been experimented with for motor vehicle purposes.

It is questionable whether numerous speed variations are essential. Although it is desirable to have two or three speed changes, the use of complicated gearing mechanism capable of a large variety of speed combinations is to be discouraged. The connection of the driving member of the variable speed and reversing gear mechanism to the driving wheels



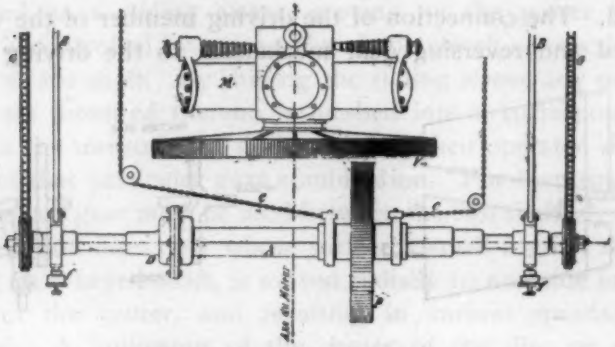
Some friction-wheel and belt variable-speed gears.

may be by either sprocket and chain or ordinary spur gearing.

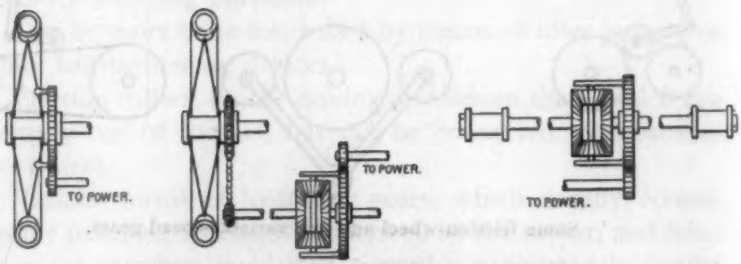
Front and rear driving wheels have been used. In going forward, it is to be noted that the reaction tends to throw the weight of the vehicle towards the rear; in the first case, therefore, on to the steering wheels and in the latter on the driving wheels. If both driving wheels are operated by a single motor, some method of compensating for the difference of travel of the outer and inner wheels in turning curves must be provided. A balance or differential gear, clutch or ratchet and pawl connection must be placed between the wheels, either in

the rotating axle where the wheels revolve with the axle, or in the driving power shaft, where each wheel revolves separately on a fixed axle, and is independently driven. The variation in wheel travel can also readily be taken care of by means of separately driven driving wheels, the motors connected thereto being properly controlled to produce the desired effect.

The Wheels, their Construction and Function.—Not only



LePape friction disc driving gear.



Simple and balance gear driving arrangements.

must this part of the conveyance act as a support, but also as a propelling medium. It is, therefore, necessary that the construction should differ in many respects from that used in the present form of vehicles. Two forces are brought to bear upon the wheel construction, one due to the rotary twist of the motive power, and the other due to the side thrust and pressure in traveling over roads that are in any way otherwise than smooth. In order to resist the twisting action of the motive

power, it is essential that the spoke should have sufficient strength on a plane with the rotation from the hub to the rim. To resist the side thrust pressure exerted through the wheel from its base to the hub, the construction must be equally strong in a direction at right angles. With the intention to, as far as possible, minimize the twisting action on the spokes due to the motive power, it has been found advisable to apply the driving power as near as possible to the rim of the wheel, and it would appear equally advisable to make the hub bearing with rotating wheels as wide as possible, to minimize the results of side thrust pressure.

Small wheel diameter is essential to reduce the height of the vehicle body. While in some instances radial wooden spokes and rims have been used, yet it appears that a metallic construction, involving tangent spokes and steel rims, is superior for many apparent reasons. This form of construction not only gives the maximum strength with the minimum of weight, but is also more in keeping with the entire mechanism. Side thrust pressure may exceed the strain exerted from the driving point to the rim. The necessary strength in this direction must therefore also be embodied in the wheel construction. A wooden wheel with broad spokes has advantages in this direction. There is, however, no reason why the same results cannot be obtained by a proper arrangement of metallic tension spokes.

Two plans are available for supporting the wheels at their centers, and both methods are applicable to both steering and driving wheels alike. One method involves the rotation of the wheel at the hub on a rigidly fixed axle. The other necessitates the fastening of the wheels directly to the end of the axle, which is then revolved in suitable bearings. Where the first method is used for the driving wheels, each wheel must be separately geared to a motor or some intermediate shaft. In such instances the balance gear is usually placed in the intermediate transmission shaft, which is suitably split, each half being connected to one side of the driven balance gears. Where some form of clutch or ratchet device is used to produce the necessary differentiation of travel in the two driving

wheels, it is possible to directly apply such mechanism to the wheel hub between the driven member and the wheel proper.

Where the wheels are fixed to a rotating axle, two somewhat similar methods are also available, but only one of these is really practicable. This involves the splitting of the axle, preferable at the center between the two bearings, and connecting the two halves together by a balance gear mechanism, the central member of which is driven. It is also possible to use some form of clutch mechanism on both sides of a centrally driven power wheel. The other method involves a continuous rotating axle, which is driven by the motor and revolves in suitable bearings. The wheels are loosely fitted to each end, being held to the rotating axle by means of clutch or ratchet devices.

In adopting the fixed axle with rotating wheels for steering purposes, it is possible to use almost any form of steering gear hereafter described. In the case of the rotating axle with fixed wheels, however, it is practically essential to adopt a continuous axle from wheel to wheel, and therefore use some fifth wheel or its equivalent method of steering.

In order to produce the best tractive results, wheel-tires must be most carefully considered. Efficiency in this direction depends greatly, with certain fixed other quantities, not only upon the grip between the tire and the surface traveled over, but also upon its flexibility. Steel and rubber tires have been used. Results seem to indicate that certain forms of the latter type, particularly the pneumatic, are productive of the best results. Not only does this form of tire give greater comfort, due to its cushioning effect, but also superior tractive effects and the reduction of side thrusts in both drivers and steering wheels. This cushioning effect, by eliminating vibration due to other types, also effects great economy in the depreciation and disturbance of the mechanism.

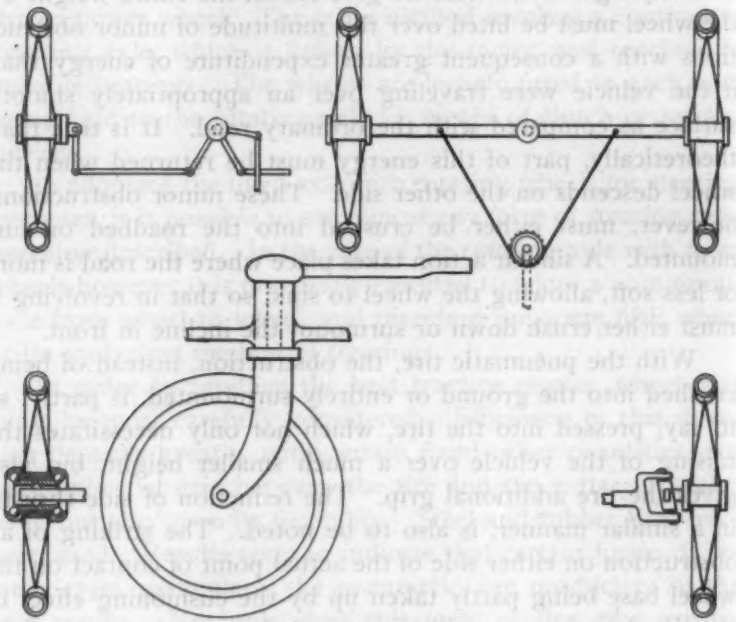
The superior traction due to the material itself is no doubt an advantage, but the cushioning or give effect is particularly notable in considering the efficient operation of such tires over the ordinary roads. What is known as road resistance is greatly minimized by the use of tires having a slight give,

instead of a rigid, unimpressionable surface. The ordinary road surface is made up of innumerable minor obstructions, closely following one another, and making a continuous track of inclines over which the wheel must be raised only to be lowered on the other side. Certainly this action occurs with great rapidity, even in traveling at ordinary rates of speed. Its effect has been experienced by all who have traveled over a cobblestone street surface in a springless wagon. With the ordinary rigid tire, where no give exists, the entire weight on the wheel must be lifted over this multitude of minor obstructions with a consequent greater expenditure of energy than if the vehicle were traveling over an appropriately smooth surface as compared with the ordinary road. It is true that, theoretically, part of this energy must be returned when the wheel descends on the other side. These minor obstructions, however, must either be crushed into the roadbed or surmounted. A similar action takes place where the road is more or less soft, allowing the wheel to sink, so that in revolving it must either crush down or surmount the incline in front.

With the pneumatic tire, the obstruction, instead of being crushed into the ground or entirely surmounted, is partly, so to say, pressed into the tire, which not only necessitates the raising of the vehicle over a much smaller height, but also gives the tire additional grip. The reduction of side thrusts, in a similar manner, is also to be noted. The striking of an obstruction on either side of the actual point of contact on the wheel base being partly taken up by the cushioning effect of the tire, less pressure will be exerted through the spokes. In the steering wheels this is particularly an important factor, as it greatly reduces the energy necessary to move them and facilitates their operation.

Pneumatic tires have therefore almost universally been adopted for this class of work. It is certainly essential that they should be impervious to ordinary injury, and should either be of a protected type, or have an ample thickness of material. It is also advisable, and apparently borne out by practical experience, that the tire should be given an ample base of contact.

Steering Wheels and Gear.—There is probably no more essential element to be considered in the construction and operation of motor vehicles than the steering mechanism. Under all conditions, and particularly at high speed, this part of the apparatus is of the utmost importance, tending greatly toward the ultimate safety of operation. It is essential, primarily, that the steering mechanism should be capable of easy and rapid operation, and yet should not be delicate or in any

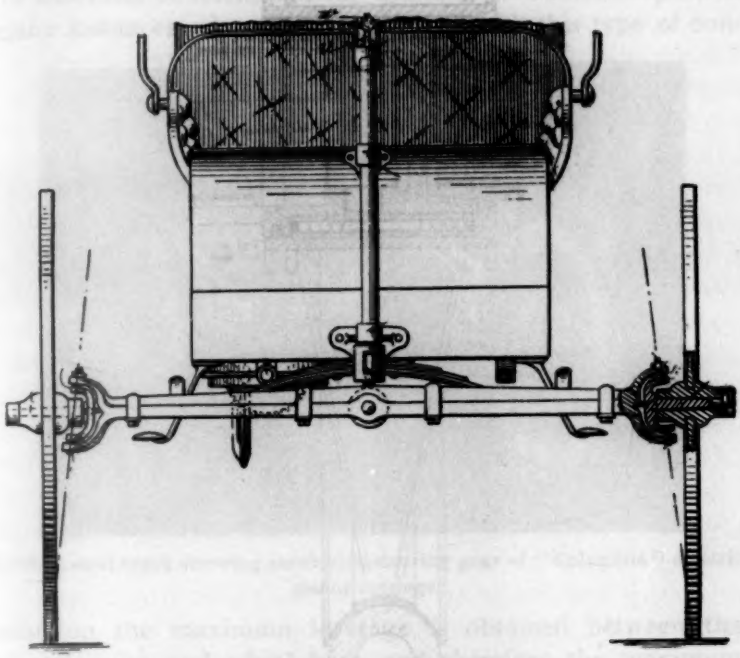


Steering gears.

way affected, unless moved by the operator. Not only should the minimum of energy be required to vary the position of the steering wheels, but the movement of the operating device, in order to produce a certain fixed position of the wheels, should be reduced to a minimum.

When an obstruction is encountered by either of the steering wheels, the tendency is to throw that wheel out of its course, and consequently a strain is exerted through the steering gear, which must be counteracted at the operating device

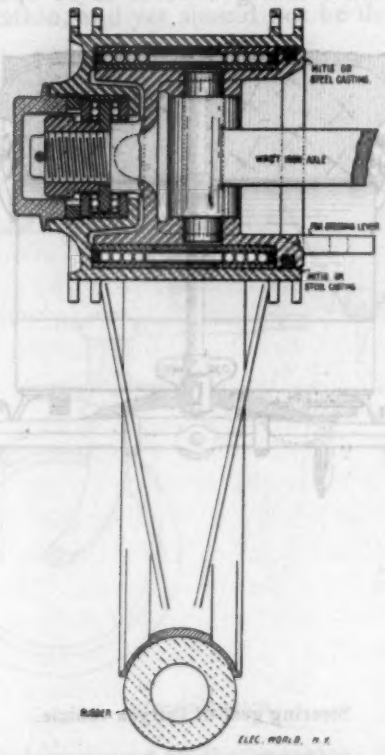
or elsewhere, in order to prevent the other wheel being similarly acted upon by the connecting medium between the two, and thus directing the vehicle out of its original path. Such actions are continuously taking place. Owing to this fact, and to the above-mentioned requirements, it is essential that the energy transmitted from the point of contact on the wheel base to the operating device be reduced to a minimum, and inversely when the steering wheel is to be operated from the



Steering gear of Duryea vehicle.

operating device. Inasmuch as the steering wheels must be pivoted at some point, either independently or jointly at a center between the two, the principle to be observed is to reduce the length of the lever between this pivotal point and the point of contact on the wheel base to a minimum, which is certainly ideal when the point of contact is on a direct line with the pivotal line. With such an arrangement the effect above mentioned will be reduced to a minimum.

Various forms of steering mechanism are available, but one method in particular seems to have been favored in the practical construction of motor road vehicles. This arrangement consists of separate and independent short axles, upon which the wheels revolve, each axle being pivoted close to the hub in suitable forks at each end of a fixed axle-tree. Ordinarily the pivotal line is directly vertical, being brought as close to the

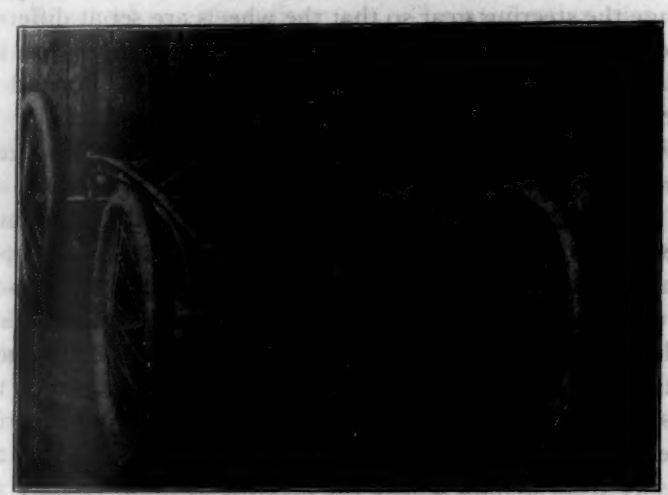


Morris & Salom hub-pivoted steering gear.

contact line as possible. Another method is to have the pivotal line at an angle from the vertical, so that it strikes the contact line on the wheel base, and therefore eliminates all leverage between these two points. This last-mentioned method, however, results in a most curious appearance of the steering wheels, when in any other position except their nor-

mal. Another plan adopted, entirely eliminating the distance between the two points, is to pivot a sleeve, on which the steering wheel revolves, centrally in the hub, on a direct vertical line with the wheel base. Each steering wheel may also be supported in a separate centrally pivoted fork, similar to the steering gear adopted in bicycle construction.

The fifth-wheel plan, or the pivoting of the axle centrally between the wheels, seems to be somewhat at a disadvantage for this class of work, and has therefore not been adopted in many instances. It will be noted that with this type of con-



Tabular steel truck showing short axle steering gear of "Columbia" electric motor carriage.

struction the maximum leverage is obtained between the pivotal point and wheel base, and therefore the maximum energy would be required at the operating device in order to hold the steering wheels steady, unless suitable gearing is used to reduce this leverage by an increased movement of the operating device.

For the operation of the steering gear proper, various combinations of levers and gears are possible. The simplest arrangement probably consists of a direct chain of levers and rods. Where an increase of movement is not objectionable in the operating device, an arrangement of gears giving a rotary

movement, which is transformed into a straight line movement, has certain advantages. The steering gear may be operated manually by the operator, or through the medium of power mechanism. With the ordinary form of vehicle, as at present developed, hand-steering seems to serve all practical purposes, and has the prime element of simplicity and positive operation. With certain forms of motive power, however—electricity, for instance—the operation of the steering wheels by power mechanism might be productive of excellent results without greatly affecting the simplicity. It is advisable to arrange the steering gear so that the wheels are set at different angles in turning curves, in order to prevent scraping on the tire. Excellent results have, however, also been obtained by a parallel setting of the steering wheels.

Front and rear steering wheels have been adopted to conform to the previously mentioned arrangement of drivers. As it is essential to operate the steering wheels with a minimum expenditure of energy, the weight resting and thrown upon them should be reduced to a minimum, consistent with reasonable construction. Where the steering wheels are therefore so placed that they are excessively weighted, the steering contrivances would necessarily be less efficient than where the pressure on the wheels is not so great. With front steering wheels the track of the vehicle is at once changed and the pressure from behind assists the steering action. Where the steering wheels are located in the rear the tendency of the drivers to continue their forward movement would seem to result in a dragging effect on the former.

Some means of permitting a vertical oscillation of the steering wheels on a pivot central between the two wheels should be provided. This greatly facilitates the steering operation over rough roads and prevents any extraordinary disturbance of the equilibrium of the vehicle proper.

Braking Appliances.—It is also of prime importance to provide devices to efficiently and rapidly arrest the movement of the vehicle. Such appliances or brakes may operate at different points between the motor device and the wheel tires, and they may be operated either by hand, foot or power.

Mechanical braking appliances may be applied directly to the wheel tire, but in this case they must be of such form as to reduce the wear on the tire to a minimum. Certain forms of roller brake shoes have given very excellent results for this purpose. Applying the braking action, however, through the medium of either brake bands or shoes to a separate revolving brake pulley, fitted to some shaft between the motor and driving wheels, seems to be a frequently adopted form. Whatever form of mechanical braking appliances are used, they must be arranged to be equally operative with rotation of the wheel in either direction. The application of a brake band or shoe in the various forms of mechanical brakes, by means of a foot or hand-operated lever, is probably the simplest arrangement, and has been found quite ample for ordinary purposes. Here again, however, can power operation be employed with very excellent results. By power operation is meant not only the direct application of a motor device to the braking appliances, but their operation by the momentum of the carriage itself. This can be accomplished both mechanically and electrically, the latter method being considered in connection with electric motors.

(To be continued.)

PRELIMINARY COMMUNICATION ON "STELLAR DYNAMICS."*

By Luigi d'Auria.

Editors Journal of the Franklin Institute:

Astronomers, since William Herschel, have recognized the study of the proper motion of stars, or "stellar dynamics," as the great problem of astronomy. Professor Simon Newcomb, when confronted with the proper motion of the now famous

*Under the above title the writer read a paper before the American Philosophical Society, May 13, 1897.

star 1830 Groombridge, which has been estimated at no less than 200 miles per second, his first thought was about the force in nature capable of producing such motion. He imagined this force in the combined attraction of all the stars of the visible universe, which, from observations, he estimated to be constituted by no less than 100 millions of suns, each on the average five times heavier than ours. The diameter of the universe containing all these suns he supposed to be equal to the distance passed over by light in 30,000 years. His calculations proved that if the star 1830 Groombridge had been attracted from infinity to the center of such universe, its velocity could not be more than one-eighth of the observed velocity of this star.

Since Professor Newcomb's estimate of the aggregated mass of the visible universe is rather liberal from a telescopic point of view, it would seem that gravitation cannot play a very important part in the phenomenon of the proper motion of stars. But then, can we suppose stars being original creations, originally projected in space with different velocities, in every imaginable direction? If we have to accept this view, we may as well say with the Mussulman, "God has willed it so," and dismiss any farther study of the subject. Fortunately, the scientific astronomer does not share in such fatalistic idea of nature, and therefore the subject in question still absorbs him almost to the exclusion of all others.

The first step towards the solution of this vast problem must be taken in the direction pointed out by Professor Newcomb, that is, we must first discover a force powerful enough in nature to account not only for the proper motion of 1830 Groombridge, but for a motion even greater than this. Without this force being first discovered, the problem must inevitably remain at a standstill. Where is this force to be found? Tyndall said that potential energy of gravitation is the original form of all the energy in the universe. The writer, firmly believing in this principle, thought, a number of years ago, that the interstellar ether, if possessed of the virtue of attraction of gravitation, might act powerfully enough upon the stars to give them their proper motion; but remembering the extreme

tenuity of ether, he refrained from prosecuting the problem. How could a substance, estimated to be about

1,880,000,000,000,000,000

times less heavy than atmospheric air, be more powerful than the 100 millions of suns, each five times heavier than ours, which Professor Newcomb had invoked to account for the proper motion of 1830 Groombridge? The force required to account for this motion must be, at least, 64 times greater than that derived from all these suns.

It was only recently that the writer, having overcome his reluctance to a certain degree, undertook the computations of the problem, and found, to his surprise, that the attraction exerted by the interstellar ether is powerful enough to account for almost any proper motion of stars. The motor was found in gravitation, acting through the same medium which nature employs for the transmission of light, heat and electricity. True, this discovery supposes ether capable of attracting matter by gravity, a fundamental question which unfortunately science has not yet settled;* but when we consider that the problem of the proper motion of stars, without this hypothesis, appears to look beyond solution, it would seem strange that nature should deny ether the attractive power of gravity, unless in doing so some great purpose was served. However, suppose that in the progress of science it should be found that some other natural, but unquestionable cause in nature, is responsible for the proper motion of stars, would the writer's investigation become fruitless? Certainly not, for the reason that failing in its original intent would indirectly settle the question that ether is gravitationless, and thus solve a problem of the greatest importance in physics.

Inspired by such promises, the writer, without making any attempt to work up the details of the problem, prepared a

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*Sir William Thomson, now Lord Kelvin, speaking of ether in his lecture on "The Wave Theory of Light" (see *Journal of the Franklin Institute*, November, 1884, p. 334), said: "We have no knowledge that the luminiferous ether is attracted by gravity; it is sometimes called imponderable because some people *vainly imagine* that it has no weight. I call it *matter* with the same kind of rigidity that this elastic jelly has."

short paper, under the title "Stellar Dynamics," which he read before the American Philosophical Society of Philadelphia, May 13, 1897. In this paper he proved that, given the ether the density as estimated by Maxwell, and the power of attracting matter by gravity, a body placed within the sphere of ether containing all the stars of the visible universe, and at a distance from the center of such sphere equal to that passed over by light in 2,200 years, would pass this center with a velocity equal to that of the star 1830 Groombridge, taking into account the attraction of the ether alone; and such body would oscillate about the same center, rectilinearly, with a period of a little over *seven million* years, which would be also the period of oscillation of every other star. This part of the problem was fully appreciated by Professor Newcomb in a note addressed to the American Philosophical Society of Philadelphia, dated May 19, 1897, in which, referring to the writer's attempt, he says: "It is not impossible that in the progress of science it may turn out to have a sound basis, so far at least as the fundamental idea is concerned. As such it would be of historic interest, and should be placed on record."

Without taking into account the mutual attraction of stars, the writer concluded that they would move in rectilinear paths in every direction. But considering such attraction, he has found that rectilinear oscillations would be incompatible, and that every surviving star would have to move on a more or less elongated elliptic orbit around the center of the visible universe, in one direction or the other.

PHILADELPHIA, PA., JULY 14, 1897.

NOTES AND COMMENTS.*

SCIENTIFIC BREVITIES.

Moissan and Dewar have lately announced the successful outcome of their joint experiments on the *liquefaction of fluorine*. The liquefaction was accomplished in Dewar's apparatus, at a temperature of —185° C. When a current of fluorine gas is passed into an apparatus maintained in the midst of liquid oxygen in tranquil ebullition at a temperature of —80° C., liquefaction

* From the Secretary's monthly reports

does not occur. But as soon as that temperature is diminished by exhausting the gas above the liquid oxygen, the liquefaction of the fluorine begins, and a clear yellow and extremely mobile liquid is obtained, which resumes the gaseous state as soon as the temperature rises. This liquid has lost the chemical activity characteristic of fluorine in the gaseous state. It no longer attacks glass, silicon, sulphur or phosphorus. Fluorine at a very low temperature, however, still attacks carburetted hydrogen, and its affinity for hydrogen seems still to exist. M. Moissan and Professor Dewar are continuing their investigations, and although solid fluorine has not yet been obtained, M. Moissan is sanguine that this astonishing result will also be secured.——Prof. Dewar, in his concluding lecture on "Liquid Air as an Agent of Research," gives an interesting account of his observations of the *effects of intense cold* on chemical action. At very low temperatures, he declared, all ordinary reactions entirely ceased, largely because everything became solid—a state of matter not favorable to chemical action. Photographic action, however, persisted to a certain extent, particularly if gelatine plates were used. This might probably be explained as indirectly due to the property possessed by organic bodies, especially the more complex ones, of phosphorescing at low temperatures. Professor Dewar also showed how cold increased the magnetic moment of a permanent magnet by as much as 20 or 30 per cent., and at the same time illustrated the magnetic properties of liquid air itself. In conclusion, he referred to the effects of extreme cold upon living organisms. In the case of ordinary putrescent matter it was found that the spores were not killed by being subjected to the temperature of liquid air, and experiments were now being carried out to discover whether seeds exposed to liquid air for at least 100 hours still retained the power of germination.——Hartley and Ramage, as the result of spectroscopic study of a large number of ores and minerals, have made the interesting observation that a number of the so-called rare elements are much more widely distributed than has hitherto been supposed. *Gallium*, for example, was found in sixty-eight out of 168 specimens, occurring in most magnetites, bauxites and blendes, and nearly half the clay ironstones and manganese ores. Rubidium appears to be even more widely distributed, occurring in most iron ores. Indium was found in thirty minerals, including all the carbonates of iron and tin ores and most blendes. Thalium, while less widespread, was frequently found. Iron and sodium were found in every specimen, and potassium in all but two, one a blende and the other a tin ore. Calcium, copper and silver were found in all but a few cases. Such a wide dissemination of gallium and indium is unexpected, and the same might be said of silver. Among metals not looked for by the authors, titanium is known to be found almost universally, and possibly the same is true of gold. ——Dr. Waterville proposes *to obtain large and transparent crystals* of various substances by mounting a small crystal in a saturated solution in a manner so that it can be rotated on itself continuously with a speed of several rotations per second. Potassium and ammonium alums, copper sulphate and sodium chlorate are said to yield very fine results by this method.——A patent has been issued jointly recently to Alfred E. Hunt, of Pittsburgh, Benjamin Talbot, of Pencoyd, Pa., and Percival Roberts, of Philadelphia, on the use of *carbide of silicon in the manufacture of steel*. Carbide of silicon is made by the Carborundum Company, at Niagara Falls, by passing an electric

current through a cove of sand mixed with coke. The finer and better grade is used as an abrasive, but there is produced considerable material which is not valuable for that purpose, and can be sold cheaply. It has been used experimentally at Pencoyd. It is split up and gives both silicon and carbon to the molten steel. It quietens and solidifies the metal and may become useful in the manufacture of castings and other specialties when solid metal is desired. It has the advantage over ferro-silicon, with 10 to 12 per cent. of silicon, because the silicon in the carbide is concentrated, the carbide containing about 70 per cent. of silicon and 30 per cent. of carbon.—— Consul Germain writes to the State Department from Zurich, Switzerland, that the new addition to the *aluminum works* of the Neuhausen Company will, when in operation, add 2,700 kilogrammes to the daily output of aluminum. Further, the Neuhausen Company is building new works, with water power to produce 10,000 horse-power at Rheinfelden, Switzerland, and has also acquired water rights for similar purposes at Lend, near Gastein, in Austria. A German-American syndicate has planned the erection of works for the manufacture of aluminum at the waterfalls of Sarpfoss, in Norway. The water power there, it is estimated, will produce 10,000 horse-power, and the plant is to be ready for operation some time in 1898.

A PROPOSED INTERNATIONAL TESTING LABORATORY.

From the *Engineering and Mining Journal* we learn that a circular recently issued by Dr. Herman Wedding, the eminent metallurgist, refers to the formation at the congress held at Zurich, Switzerland, in 1895, of the "International Society for the Unification of the Methods of Testing Materials of Construction." The council of this society has decided that in order to carry on its work to the best advantage the work hitherto done in many isolated places should be brought together in a common focus, when it could be classified, compared and reduced to a standard.

Such a central laboratory would also have the task of following the progress of both industry and science; of examining all new methods of any importance brought forward in various quarters; of searching for new methods whenever new problems were presented; and of serving as a guide to individual chemists. The establishment of a central laboratory of the kind indicated is far from being an easy matter. In the first instance, national feelings must be reckoned with. It has been universally felt that only a neutral country could be the seat of such an institution, and the unanimous choice fell on the city of Zurich, the intellectual capital of Switzerland, and the seat of the last congress, with scientific institutions of high standing, and furnished with a laboratory for testing materials of construction, erected on the most modern principles; while, on the other hand, no commercial jealousies could possibly be awakened by selecting a country devoid of ironworks of any magnitude.

Whatever place might have been chosen, the first difficulty arising would have been that of obtaining a proper locality for the central laboratory. Of course, it was out of the question to raise capital for building such a laboratory in a foreign country. But, fortunately, it has been possible to secure the use of ample accommodation in the magnificent chemical laboratory of the Fed

eral Polytechnic School. The Federal Council has been pleased to grant the use of these rooms, free of rent, for the projected central laboratory, and thus the great difficulty of location has found its solution in the most favorable way. The next step, that of finding a fit and proper head for the central institution, has been successfully accomplished by securing the services of a most competent specialist, Hanns von Jüptner, chief chemist of the Neuberg Iron and Steel Works in Austria.

Only one step now remains to be taken, raising a fund for the maintenance of the central laboratory, that is, for the salaries of the director and his assistants, for the cost of reagents and other incidental expenses, and further, for remunerating the assistants of some eminent chemists in various countries, who have kindly undertaken to take part in the work proposed. For these purposes $10,000 per annum is required, and it would be impossible to start the laboratory unless the payment of this expense was secured for, say, ten years. There is no chance of obtaining these funds either by government grants or from the institutions existing in various countries. The only practicable way is, evidently, to obtain subscriptions from the ironmasters of the various important iron-making countries. Looking at the immense importance such a central laboratory is likely to acquire for the whole of the iron industry, and the very large pecuniary benefit ultimately following therefrom, it is suggested that large iron works might contribute, say $250 per annum each for that purpose. It is desirable to have these contributions come from as many countries as possible.

It may be mentioned that the firm of Krupp, of Essen, has already subscribed $250 per annum for this purpose, while the Austrian iron masters have made a handsome beginning by subscribing a sum of $1,750 per annum. All the other iron-producing nations, it is hoped, will follow.

It may be added that the results secured will be reported at the next meeting of the International Society, which will be held at Stockholm, in Sweden, on August 23d.

ARTIFICIAL PRODUCTION OF DIAMONDS.

Prof. Wm. Crookes gave the following interesting references to the probable origin of the diamond, and the efforts hitherto made to produce it artificially, in a recent lecture at the Royal Institution in London.

The lecturer stated that speculations as to the probable origin of the diamond have been greatly forwarded of late years by improved means of obtaining high temperatures; and through the successful experiments of Moissan, microscopic diamonds have been made in the laboratory. He had provided a most powerful dynamo, especially made for the purpose, weighing 4½ tons, and when driven by a 50 to 75 horse-power engine generating a current in the electrical furnace of 700 to 800 ampères at 70 volts, yielding a heat of from 3,500 to 5,000° C. In the process of making diamonds, the first necessity was to select pure iron and to pack it in a crucible with pure charcoal from sugar. Half a pound of this iron was then put into the body of the electric furnace and the arc formed close above it to utilize the electrical current passing through it. The iron rapidly melts and saturates itself with the carbon. After a few minutes it is heated above 4,000°—a temperature at which the

lime of the furnace melts and volatilizes. The current is then stopped, and the crucible is plunged beneath the surface of cold water, where it is held until it diminishes to a dull-red heat. The sudden cooling solidifies the outer layer of iron, and holds the inner molten mass in a tight grip. The expansion of the inner liquid in solidifying produces an enormous pressure, and the dissolved carbon separates out in a transparent dense crystalline form - in fact, as diamond. Then commences the more tedious part of the process, the attacking the metallic mass with solvents to liberate the diamonds, the crystals of graphitic oxide, carbonado and bort—the cleansing operations being repeated until all the well-washed grains are collected and examined under the microscope. The laboratory diamonds burn in the air before the blow-pipe into carbonic acid, and in luster, crystalline form, optical properties, density and hardness are identical with the natural stones. Many circumstances, he pointed out, led to the conclusion that the diamond of the chemist and the diamond of the mine are akin as to origin, and that the diamond genesis must have taken place at great depths, under enormous pressure. Molten iron could have held the carbon in solution, and all the varieties of carbon crystals, and even the different tints of diamonds from various mines and geographical areas, could be accounted for on this theory. It is certain, from observations made at Kimberley, corroborated by the experience gained in the laboratory, that iron at a high temperature and under great pressure will act as the long-sought solvent for carbon, and will allow it to crystallize out in the form of diamond—conditions existent at great depths below the surface of the earth. But it is also certain, from the evidence afforded by the Arizona and other meteorites, that similar conditions have likewise existed among bodies in space.

PAINT AS A PROTECTION TO METALLIC STRUCTURES.

The Department of Public Works of New York City is about to carry out a test of the preservative qualities of various kinds of paint which should be of the greatest interest to all engineers and builders, and should provide them with some much-needed data. We learn from the *Scientific American* that the experiments are to be made on a massive steel viaduct which carries One Hundred and Fifty-fifth Street across the elevated tracks of the Manhattan Railway Company. The test is to be carried out in a thoroughly scientific and practical manner, and great care will be taken to shut out any disturbing element which might affect the value of the results. A tight board roof will be built beneath the viaduct to shield it from the smoke of the locomotives. The first operation will be to clean off all the old paint and rust by means of the sand blast, and this will be done until the surface of the metal presents a clean and bright appearance. The paint will be put on within three hours from the time the cleaning is finished.

The various manufacturers will be invited to tender bids and provide specimens of their paints, and these samples will be used in painting the structure. The precautions which are being taken will insure that the different varieties of paints will have the same opportunities to show their good qualities, and the results will be watched with close attention by those who are responsible for the erection and preservation of all classes of structural steel and iron work.